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# Field Investigation of Biological Toilet Systems and Grey Water Treatment

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A health risk assessment was performed concurrently using environmental health experts to estimate the probability that a significant failure of a particular on-site waste treatment and disposal system would occur. The technique used by the environmental health experts is an objective decision-making technique that may be used by regulatory officials to evaluate new technologies where there is an absence of definitive test information. This assessment results in a probability that is expressed in relation to the estimated risk of a known system, the septic tank-soil absorption system.

Model education and surveillance-monitoring frameworks are presented. Since the user may need guidance during siting and operation and in the event of system failures, third-party management is strongly advised.

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# FIELD INVESTIGATION
# OF
# BIOLOGICAL TOILET SYSTEMS
# AND GREY WATER TREATMENT

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# FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxic Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This study represents an effort to document the state-of-the-art of human excrement composting, the operational characteristic of seven types of black waste waterless toilet systems, and to present an example of an objective decision-making technique which will allow new technology to be examined on a case-by-case basis considering all of the relevant environmental factors.

Francis T. Mayo
Director
Water Engineering Research Laboratory
Office of Research and Development

# ABSTRACT

The objective of the field program was to determine the operational characteristics and overall acceptability of popular models of biological toilets and a few select grey water systems.

A field observation scheme was devised to take advantage of in-use sites throughout the State of California. Field performance was recorded monthly on forms which were developed to record site conditions such as pile temperatures, odors, and vector observations. Samples of the decomposition chamber pile and the end products were taken for laboratory analyses that included both physical and microbiological parameters. Grey water influent and effluent were also analyzed.

Each discrete system was evaluated considering site observations and the results of laboratory analytical work performed on individual samples. The measurement of the following key process determinants was attempted: volatility and type of materials, moisture content, carbon/nitrogen rates, temperature, and pH. Overall observations for seven generic types of biological toilets indicated generally unacceptable levels of biological decomposition were occurring within the studied systems. Most toilet systems studied appeared to suffer from inadequate or improper design, siting, construction, and/or operation and maintenance. Influent and effluent from three types of grey water systems were also analyzed. Most grey water systems failed to improve the quality of raw grey water. However, the number of systems examined was small.

A health risk assessment was performed concurrently using environmental health experts to estimate the probability that a significant failure of a particular on-site waste treatment and disposal system would occur. The technique used by the environmental health experts is an objective decision-making technique that may be used by regulatory officials to evaluate new technologies where there is an absence of definitive test information. This assessment results in a probability that is expressed in relation to the estimated risk of a known system, the septic tank-soil absorption system. In general, the approach identified critical considerations which were later verified by field and laboratory observations. When used in combination with a thorough regulatory and user education program, the technique can be an important tool for nontraditional technologies.

Model education and surveillance-monitoring frameworks are presented. Since the user may need guidance during siting and operation and in the event of system failures, third-party management is strongly advised.

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Karol M. Enferadi is a sanitary engineer for the State of California, Department of Health Services, with the Sanitary Engineering Branch. In addition to the task of preparing this report, Mrs. Enferadi served as the field project coordinator during the data collection phase between August 1979 through June 1980.

Robert C. Cooper is professor with the School of Public Health, University of California at Berkeley. Dr. Cooper chaired the Health Effects Committee and provided guidance during the preparation of the Health Risk Assessment Report.

Storm C. Goranson prepared the Needs Survey and education framework while employed as a professional engineer by Storm Engineering, Davis, California. Mr. Goranson is currently associated with Environmental Engineering.

Adam W. Olivieri is a sanitary engineer with the State of California Regional Water Quality Control Board. Mr. Olivieri prepared the Risk Analysis Report as a doctoral condidate at the School of Public Health, University of California at Berkeley.

John H. Poorbaugh is a biologist with the State of California, Department of Health Services, with the Vector Biology and Control Branch. Dr. Poorbaugh served as project director and was responsible for preparation of report findings about vectors.

Malcolm Walker coordinated the public and private sector participation and contracted for the development of the Needs Survey and education framework while employed as an intergovernmental program analyst with the Governor's Office of Appropriate Technology. Mr. Walker was also primarily responsible for the preparation of an earlier version of the project report. Mr. Walker is currently associated with Metcalf and Eddy.

We are particularly indebted to Barbara A. Wilson, who served as the project's biologist. In addition to the task of training field personnel, she developed a uniform method of observing and sampling each site. In her role of sole coordinator between sampling personnel and the project, her sustained interest and perseverance greatly aided resolution of many daily crises which made completion of the project possible. In addition to assuming the responsibility for sampling nearby sites, her expertise as an entomologist was an asset to the project.

Assays of the toilet and grey water samples from August 1979 through June 1980 were conducted by three Department of Health Services laboratories. The Sanitation and Radiation Laboratory is directed by Dr. Ben Tamplin; the Microbial Disease Laboratory by Dr. Ted Midura; and the Viral and Rickettsial Disease Laboratory by Dr. Richard Emmons.

## SECTION 1
## INTRODUCTION

At least 25 percent of the population of the United States is served by some form of on-site sewage treatment and disposal system. A smaller percentage of individuals are segregating toilet or "black" wastes from the rest of the household wastes for separate treatment and disposal. Nonwater carriage devices are an alternative for treating those black wastes for a variety of reasons: (a) dwindling natural resources suggest a conserved lifestyle; (b) potable water resources are limited or unavailable; (c) future grant-funded public utility projects are unlikely; and (d) available building sites are not always suited for subsurface–leach field applications. Although some individuals are able to construct their own toilet and grey water facilities, most choose to purchase manufactured devices. Many such proprietary products are currently available on the marketplace.

Proprietary devices have been strongly promoted during the past decade; however, there is a lack of data to support performance claims. Industry-wide standards do not exist although recently published National Sanitation Foundation Standard Number 41 sets forth voluntary levels of electrical, mechanical, and operational performance. Nonetheless, performance under actual use conditions is undocumented and remains largely unknown.

Each type of toilet and grey water system varies in size, shape, and appearance; however, the internal processes used by the toilets for decomposition of human wastes are similar. A paucity of information exists at the present on that biological decomposition process. Although the final product from these toilets has been promoted as suitable for use as a fertilizer or soil amendment, there is little data available to indicate that this use is safe. Further information needs to be developed for the proper treatment and disposal of household grey waters.

This study focuses on identifying performance characteristics, operational and maintenance problems, and health risks for seven types of nonwater carriage toilets and grey water systems.

# SECTION 2
# CONCLUSIONS

## "COMPOSTING" TOILETS

None of the "composting" toilet system installations observed in this study successfully performed their intended functions. The results of this field investigation indicated that negligible to highly variable decomposition of the toilet wastes occurred due to a number of technological and informational shortcomings. With the exception of the pit privy all of the tested compost toilets are purported to rely on some form of a confined, continuous, aerobic biological decomposition process to treat combinations of human excrement and combustible carbonaceous material. This study was unable to determine whether continuous biological composting is a viable process in this application because none of the monitored systems exhibited completely satisfactory performance.

There was evidence to suggest that performance varied from mere storage of human excrement to partially successful decomposition of organics and/or reduction of microbiological hazards. The physical presence of solids at the "final" chamber of a toilet system had no bearing on whether or not treatment had occurred. The rate at which excrement moves through a system was solely dependent upon system capacity and rate of usage. In addition, the physical appearance and odor characteristics were not reliable indicators of the biological degradation process.

Most of the system users were alternative technology advocates, yet they were generally unable to make their systems work satisfactorily. Few of these systems displayed any significant evidence of biological composting during 17 months of observation. The systems repeatedly showed evidence of conditions unfavorable for the occurrence of biological composting such as inadequate bulking agent use, too much moisture, ammonia and hydrogen sulfide odors indicating anaerobic conditions, insect vectors, and ambient temperatures. The users were generally not well informed about the particular sensitivities of their systems to improper operating procedures. Since a majority of the users were unwilling and/or unable to perform recommended operation and maintenance procedures, it is unclear whether any of the toilet systems studied were capable of acceptable performance. In addition, the individual user may not be willing or able to recognize the most prudent disposal option. The primary source of user information was the manufacturer's instructions which uniformly lacked facts necessary for an understanding of the process and roducts. This often contained unsubstantiated and misleading information about the quality and safety of the end products. This may have contributed to the users' false sense of safety about residuals from the toilet systems.

Some apparent problem areas identified with the proprietary toilet units studied were:

1. Small or awkwardly placed openings limited physical access to the stored excrement which either prevented or hindered the users from performing routine maintenance.

2. Existing internal structural design features or mechanisms such as a slanted chamber bottom or internal rotors intended to mix and/or aerate solids failed to do so.

3. Some of the proprietary devices suffered structural failures such as topping bar handle breakage under normal use, air baffle collapse under the weight of the excrement pile, metal fastener corrosion and inefficient latches, and leaking holding chamber design and other construction defects.

4. Electrical components such as heating elements malfunctioned and/or did not perform as intended.

5. Venting systems employed in the studied units could not maintain aerobic conditions within the excrement pile nor could they mitigate excessive moisture.

6. Stored excrement attracted and harbored insects although the units were reportedly designed to prevent this problem.

7. The manufacturer's instructions to the user were not always available in English. When instructions were available, they uniformly lacked information necessary to understand the degradation process and often contained unsubstantiated and misleading information about the quality and safety of the end products.

Some of the problem areas identified with homeowner-built toilet units are as follows:

1. Poor siting allowed excrement chamber to become inundated with surface and/or storm runoff; some subsurface excrement chambers were flooded by rising groundwater table during wet weather.
2. Inadequate or missing seals and/or screens over all openings allowed insect and rodent vector access to excrement pile.
3. Cumbersome access doors hindered vault owners during operation and maintenance while the lack of access to drum contents prevented user maintenance activity.
4. Uncoated drums frequently corroded.
5. When the recommended scissor-jack arrangement was not used to position drum in place, full drums were difficult to remove for ultimate disposal.

## GREY WATER

Most of the grey water treatment systems studied also failed to successfully perform their function. The results of analytical work performed during this investigation demonstrated that individual households produced highly variable grey water with quality similar to raw domestic sewage. Merely separating toilet wastes from the remainder of the household waste stream does not insure personal or public safety. Both clothes washing and bathing activities produced a wide range of indicator organisms with the major portion of coliform organisms detected being of fecal origin. None of the treatment and/or segregation schemes resulted in a reduction of microbiological hazards or in discernible wastewater treatment. Only one treatment scheme, involving a series of settling tanks, resulted in consistent removal of particulate matter.

Nearly all reuse schemes involved seasonal irrigation of landscape and/or food crops. However, most systems were used year-round and had no provisions for ultimate disposal of poor quality grey water, surge loads, and/or storage when use was contraindicated by wet weather. Homeowners did not establish a routine program for operating and maintaining their systems; they were in general only aware of them when malfunctions or problems occurred and, even then, did not place a high priority on resolving the matter.

## HEALTH RISKS

The health risk associated with on-site disposal systems was estimated with the use of methods (probability matrix and Delphi techniques) that render explicit the judgments made by environmental health experts. The results indicate that the risk of a public health problem occurring in a septic tank-soil absorption system during the lifetime of the system would be 1 chance in 500,000. The public health risk associated with the various combined black and grey water disposal systems under consideration was estimated to be from 1 chance in 30,000 (true composting, mouldering, and drum toilet waste buried and grey water to landscape) to 1 in 2,300 (drum toilet waste and grey water to food crops). Those systems in which food crops were not involved in the disposal scheme received lesser health risk estimates than when food crops were involved. For example, the risk estimated to be associated with true composting systems in which solids are buried and grey water used for landscape irrigation was 1 in 30,000 while with grey water application to food crops the risk was estimated to be 1 in 7,100, an increase in risk by a factor of about 4. Numerical values are relative rather than absolute and can be used for comparative purposes between different systems.

System maintenance was identified as a potential for increased health risk to individual users. However, differences in the level of system maintenance would have a limited effect on risk to the community's health depending upon population and system density.

# SECTION 3
# RECOMMENDATIONS

## BIOLOGICAL "COMPOSTING" TOILETS

Since the majority of users did not perform needed operation and maintenance properly and since none of the units were shown to accomplish biological decomposition consistently under field conditions, the following are recommended:

1. Examination of alternative technologies, including biological toilets, should continue to be investigated to determine safe treatment and disposal options for household wastes.

2. To make the use of biological toilets an acceptable practice in terms of users and public health, the design, construction, and siting of proprietary systems should be reevaluated with special emphasis on common design problems as well as for changes necessary to enhance and/or promote biological decomposition.

3. Based upon the results of this and other prior studies, the use of a biological toilet cannot be unconditionally recommended for individual homes.

4. If local circumstances are amenable to the use of such systems, they should only be used with acceptable provisions made for treatment and ultimate disposal of the contained excrement until such time as these systems demonstrate acceptable levels of solid waste treatment.

## GREY WATER

Since only one of the grey water treatment systems studied performed its intended purpose and since individual households produce highly variable grey water with a quality similar to raw domestic sewage and since none of the segregation schemes resulted in reduced microbiological risks, the following are recommended:

1. The direct watering of landscape or food crops should be prohibited until systems of proven effectiveness, approved and inspected by local health authorities, are employed.

2. If the treatment system reliably removes particulates, subsurface irrigation of ornamental landscape and trees appears acceptable.

3. An acceptable subsurface sewage disposal system should be available for disposal of any excess quantity of grey water, poor quality grey water, and wastes produced during periods of wet weather.

## INSTITUTIONAL CONSIDERATIONS

The ultimate determination of the suitability of a technology from the point of view of public health protection must be made by the appropriate governmental agency. Assessment of public health risk constitutes only one-half of the essential comparison that should be made; the remainder is a matter of the personal and social values of However, through sound research and demonstration projects and with the use of objective decision-making techniques such as the Delphi approach coupled with a strong education program, potential users and regulatory officials can make appropriate decisions.

Because individual systems lend themselves to regulation during siting, operation, and in the event of their failure, third-party regulation and maintenance are strongly recommended. A program containing the necessary legal authorities required to carry out these functions would assure high standards of construction and consistent maintenance quality as well as the means to abate failures. New users should receive information and guidance; all users should be given explicit directions for disposal of all end products since acceptable options can vary from one area to another.

# SECTION 4
# BACKGROUND

## 4.1 BASICS OF COMPOSTING

Ancient civilizations were known to use composted human excrement to improve soil fertility. Present understanding about the application of those processes for the sanitary treatment and disposal of human waste products has advanced in several areas but remains unquantified particularly in the mesophilic range of temperatures. The following is a summary of those factors which have been identified as key determinants in the composting process, specifically the biological toilet system. Other composting techniques such as windrow and the aerated static pile will not be discussed.

The confined process as used in biological toilets employs an enclosed container. Models of proprietary dry toilets, the 55-gallon drum, and the bin composter are all examples of a confined system. Although each generic type is unique, the basic process steps are similar.

Composting is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus-like material.[1] Under controlled conditions, aerobic microorganisms partially decompose moist solid organic matter. Environmental factors influence the speed and course of the composting cycle. The key determinants in this process are volatility and type of materials, moisture content, oxygen concentration, carbon/nitrogen ratio, temperature, and pH.[2]

The composting process treats solid wastes, it does not render mixtures of human excrement and bulking agents totally inert. The composting process is considered complete when the product can be stored without giving rise to nuisances such as odors and vectors and when pathogenic organisms have been reduced to a level such that the material can be handled with minimum risk.[2] The principal objectives of composting are therefore:

1. To kill most pathogens;
2. To stabilize most degradable organic matter;
3. To produce a uniform, relatively dry end product free from objectionable and harmful components;
4. To conduct the process in a sanitary manner, free from vectors and odors as inexpensively and as dependably as possible.

### Biological ("Composting") Toilets

A biological ("composting") toilet is a sewerless on-site system where feces, urine, toilet paper, and organic kitchen wastes are collected, excess water evaporated, and solid material decomposed to a soil-like product.[84] These toilets are generally divided into two groups according to their size. Smaller units are self-contained within the toilet room, while larger units employ separate reactor or decomposition tanks in areas below the toilet room where the toilet fixture is located. Larger units generally have greater capacities. In Scandinavia, all continuous service units are equipped with fans and heating elements to maximize evaporation, which is ordinarily the limiting factor in determining toilet capacity.

### Volatility and Type of Materials

The quantity and composition of wastes introduced to the toilet system vary with the season, the number and age of system users, the social and dietary customs, the use of household garbage grinders, and the type of bulking agents. The mixture within one particular system should be fairly uniform and therefore be manageable. The major purpose of a dry toilet system is to treat human excrement. The following is a summary of the physical and chemical composition of human excrement.[3]

**TABLE 4.10 PHYSICAL AND CHEMICAL COMPOSITION OF HUMAN EXCREMENT**

*Human feces without urine*

*Approximate quantity*

0.3–0.6 pound (135–270 g) per capita per day moist weight
0.08–0.16 pound (35–70 g) per capita per day dry weight

*Approximate composition*

| | |
|---|---|
| Moisture content | 66%–80% |
| Organic-matter content (dry basis) | 88%–97% |
| Nitrogen (dry basis) | 5.0%–7.0% |
| Phosphorus (as $P_2O_5$) (dry basis) | 3.0%–5.4% |
| Potassium (as $K_2O$) (dry basis) | 1.0%–2.5% |
| Carbon (dry basis) | 40%–55% |
| Calcium (as CaO) (dry basis) | 4%–5% |
| C/N ratio (dry basis) | 5–10 |

*Human urine*

*Approximate quantity*

Volume: 1 3/4–2 1/4 pints (1.0–1.3 litres) per capita per day
Dry solids: 0.12–0.16 pound (50–70 g) per capita per day

*Approximate composition*

| | |
|---|---|
| Moisture content | 93%–96% |
| Organic matter content (dry basis) | 65%–85% |
| Nitrogen (dry basis) | 15%–19% |
| Phosphorus (as $P_2O_5$) (dry basis) | 2.5%–5% |
| Potassium (as $K_2O$) (dry basis) | 3.0%–4.5% |
| Carbon (dry basis) | 11%–17% |
| Calcium (as CaO) (dry basis) | 4.5–6% |

In addition to human fecal matter, material classified as bulking agents are often added to the dry toilet system to keep the contents porous for aerobic degradation. The type and quantity of these bulking agents are extremely variable, depending on local availability and personal preference. Wood chips, saw dust and straw are commonly used for porosity and moisture control. A source of nutrients for large biological toilets might be found in garden clippings, kitchen produce scraps, sawdust, or rice hulls. Toilet paper is an expected additive. The quantity and type of bulking agent(s) employed will vary with the design of the toilet. The resultant mixture must be porous, structurally stable, and capable of self-sustaining the decomposition reaction of composting.[2] The exact composition of successful combinations of human wastes and bulking agents has been widely reported in differing terms. Not more than 10 to 20 percent by weight of human excrement will compost when combined with 80 to 90 percent of combustible bulking agent.[4] Ratios of 1 and 1½ gallons of excrement to one cubic foot of refuse will compost satisfactorily while two gallons per cubic foot becomes a soggy mass.[5] Another report[3] suggests that excrement equal to 10 to 25 percent of pile weight will compost satisfactorily; however, up to 50 to 60 percent excrement will compost if mixed with dry straw and farm manure.

The above discussion mixes thermophilic composting with the biological degradation process which occurs in these toilets. Since the energy released from composting the dry solids of human wastes could only equal about 10 to 20 percent of the energy needed to evaporate the excess liquid and the ratio of pile volume to surface is very small, no significant increase in pile temperature could be expected. Also, the quantities of bulking agents described above are valid only where the liquid is to be absorbed by the bulking agent, which is only feasible with very large toilet reactor chambers such as the Clivus Multrum. Some bulking agent addition is desirable for these toilets, however, to insure porosity of the pile.

## Moisture Content

Theoretically aerobic decomposition can proceed at any moisture content between 3 to 100 percent if adequate aeration is provided. Generally, if the mixture is over 60 percent moisture, water may displace air from the interstices between particles resulting in anaerobic conditions and adversely change the structural integrity of the mixture. Moisture less than 40 percent may inhibit the rate of bacterial action until microbial action ceases at about 12 percent. The optimum moisture content for a particular system will vary with the type of bulking agent used. A strong fibrous material such as straw will allow for a greater moisture content without compromising the structural integrity of the pile by preventing it from becoming soggy, compact, and losing the air interstices. If the bulking agent is granular like ash or sawdust and lacks structural integrity, aerobic conditions may be difficult to maintain above 70 percent moisture. The best approach for moisture control is to maximize evaporation of the excess moisture in human body wastes. The most effective bulking materials to handle periodic excessive liquid are straw and fibrous material. However, dry sawdust and soil are satisfactory. If the moisture content drops below 40 percent, water can be added by spraying. Natural ventilation will generally not supply adequate quantity of air to evaporate excess moisture in order to permit free flow of air through pile voids.

## Aeration/Oxygen Concentration

Air is necessary to first evaporate the excess moisture which fills the pores of the material. Aerobic organisms require nutrients, moisture and by definition, oxygen to decompose organics. Aeration to supply oxygen can be accomplished mechanically by turning, by a blower or fan forcing air through a perforated floor or pipes under the material, or by a combination of both techniques. If oxygen is inadequate, less efficient and slower anaerobic decomposition can result, with the production of methane and the release of offensive, odoriferous sulfides and mercaptans.

The amount of aeration necessary is governed primarily by the moisture content and to a far lesser extent by the type of materials being composted. A pile with too high of a moisture content will not have pore space available for air. EPA has suggested the optimum oxygen concentration in thermophilic composting mass is between 5 and 15 percent by volume, because greater than 15 percent would result in a temperature decrease due to the greater air flow.[2] The controlling factor for biological toilet aerobic degradation is the moisture content of the pile since temperature increases due to biological activity are small.

## Carbon/Nitrogen Ratio

Microorganisms use both carbon as an energy source and nitrogen as an essential nutrient for growth. A C/N ratio of raw decomposable material between 25 and 30 has been shown to be most satisfactory for optimum decomposition rate and nitrogen loss. When composting human wastes, this range of the C/N ratio is desirable to ensure adequate heat production for pathogen destruction. Lower C/N ratios increase the loss of nitrogen by volatilization as ammonia, and higher values lead to progressively longer composting times because nitrogen becomes growth-rate limiting.[2]

The determination of the C/N ratio by analytical techniques of the material undergoing composting is difficult and time consuming. A New Zealand report[6] suggests that for composting, a satisfactory estimate of the carbon content can be made from the percentage of ash content by the following equation:

$$C = \frac{100 - \%\ \text{Ash}}{1.8}$$

This was verified to be within 2 to 10 percent of carbon determinations by analytical methods.[7] Data for an approximation of the nitrogen content of various materials used in composting are given in Table 4.12.[3] The role of the C/N ratio in biological toilets is generally minor in terms of the rate of organic matter degradation.

TABLE 4.12 APPROXIMATE NITROGEN CONTENT AND C/N RATIOS OF SOME COMPOSTABLE MATERIALS (DRY BASIS)

| MATERIAL | N (%) | C/N |
|---|---|---|
| Urine | 15–18 | 0.8 |
| Blood | 10–14 | 3 |
| Fish scrap | 6.5–10 | – |
| Poultry manure | 6.3 | – |
| Night soil | 5.5–6.5 | 6–10 |
| Meat scraps | 5.1 | – |
| Young grass clippings | 4.0 | 12 |
| Sheep manure | 3.75 | – |
| Pig manure | 3.75 | – |
| Lettuce | 3.7 | – |
| Cabbage | 3.6 | 12 |
| Tomato | 3.3 | 12 |
| Onion | 2.65 | 15 |
| Pepper | 2.6 | 15 |
| Grass clippings (average mixed) | 2.4 | 19 |
| Horse manure | 2.3 | – |
| Turnip tops | 2.3 | 19 |
| Buttercup | 2.2 | 23 |
| Raw garbage | 2.15 | 25 |
| Farmyard manure (average) | 2.15 | 14 |
| Bread | 2.10 | – |
| Cow manure | 1.7 | – |
| Wheat flour | 1.7 | – |
| Whole carrot | 1.6 | 27 |
| Mustard | 1.5 | 26 |
| Potato tops | 1.5 | 25 |
| Fern | 1.15 | 43 |
| Combined refuse, Berkeley, California (average) | 1.05 | 34 |
| Oat straw | 1.05 | 48 |
| Whole turnip | 1.0 | 44 |
| Timothy | 0.85 | 58 |
| Wheat straw | 0.3 | 128 |
| Rotted sawdust | 0.25 | 208 |
| Raw sawdust | 0.11 | 511 |
| Bread wrapper | nil | – |
| Newspaper | nil | – |
| Kraft paper | nil | – |

**Temperature**

Biological decomposition can be classified by the temperature range at which decomposition occurs. Aerobic biological decomposition that occurs as a result of the action of thermophilic "heat-loving" microorganisms can produce energy sufficient to heat the composting mass to temperatures in the range of 25°–85°C. Organic matter is biochemically degraded to a humus-like material. If oxygen is inadequate, less efficient and slower anaerobic decomposition can result, with the production of methane and the release of offensive, odoriferous sulfides and mercaptans.

Moderate temperature or mesophilic stabilization commonly occurs in nature in the range of 15° to 43°C. A mesophilic system with sufficient mass in an insulated enclosure could suggest a low degree of composting activity due to the presence of unfavorable conditions such as inadequate organic matter, poor aeration, or too much moisture so that pathogen-killing temperatures are not reached.[70] The long duration required by the mesophilic system to eliminate pathogens is well documented, whereas there are few published data available to quantify the time requirements for mesophilic stabilization.[71, 72, 73] Although aerobic mesophilic decomposition is feasible, it may not necessarily destroy pathogens if the decomposition period is limited.

Thermophilic composting is a more rapid aerobic process where temperatures of about 60°C for extended periods can destroy disease-producing organisms. Continuous aeration of the composting pile is necessary to achieve and maintain these high temperatures.Thermophilic aerobic composting is defined by regulation to include agitation with air or oxygen, a residence time of 10 days at 55°–60°C with a volatile solids reduction of at least 38 percent.[2] It is logical to expect that given enough time, mesophilic decomposition will occur due to a combination of environmental processes. One issue here is whether the toilet systems under scrutiny are able to foster conditions favorable for the occurrence of biological decomposition in both the mesophilic and thermophilic ranges.

The following is a summary of the minimum, optimum, and maximum temperature ranges for aerobic decomposing bacteria.[1]

TABLE 4.13 TEMPERATURE RANGES FOR THERMOPHILIC AND MESOPHILIC BACTERIA

| BACTERIA | MINIMUM | OPTIMUM | MAXIMUM |
|---|---|---|---|
| Thermophilic | 25°–45°C<br>77°–113°F | 50°–55°C<br>122°–131°F | 85°C<br>185°F |
| Mesophilic | 15°–25°C<br>59°–77°F | 25°–40°C<br>77°–104°F | 43°C<br>109°F |

To achieve optimal temperatures throughout the pile, proper ratios of excrement to combustible refuse and frequent mechanical mixing to aerate are all mandatory operational requirements which suggest that aerobic composting is normally operated on a batch basis. The quantity of excrement and bulking agent in these toilets is too small to naturally attain thermophilic decomposition.

Two methods of combining excrement with bulking agent have been proven successful for confined thermophilic composting.[3] The first method is to pour a batch of excrement into the center of a stack of compostable bulking material that has been allowed to compost two to four days prior to the addition of the fecal material. When this mixture has been well heated and partially stabilized, a second addition of excrement can be made. A total pile height of 3–4½ feet is desirable, depending ultimately on ambient temperatures, the carbon/nitrogen ratio and the moisture content. The second technique is to alternate layers of excrement and bulking agent.

The confined system may or may not have bottom drains to assist with liquid drainage and aeration. System walls should provide insulation. Frequent mechanical turning is necessary to maintain aerobic thermophilic conditions. A confined system becomes anaerobic if not turned every few days.[56] When anaerobic, there is no opportunity to attain the required temperatures to destroy pathogens. Controlling flies and odors are additional problems under anaerobic conditions.

### pH

Measurement of pH is a convenient indirect tool for determining the status of the thermophilic process. Each composting pile will develop its own pH change pattern that is dependent upon the nature of the materials and the particular decomposition process. Fresh excrement has a pH value near neutrality. Aerobic decomposition initially results in an acid phase with a corresponding pH drop to a range of 4.5 to 5.5. After a period of time, one to four days, both the pH and temperature rise to an alkaline pH range of 8 to 9 where temperatures peak in the thermophilic range. As the composting process continues over time, the pH reduces to near 7. The use of pH as a tool for controlling mesophilic aerobic decomposition of the type employed in biological toilets has not been delineated.

### Summary

While process determinants are an aid for site monitoring and observation tasks, they do not easily translate into end product characteristics. The composting process is considered complete when the product can be stored without giving rise to nuisances such as odor and vectors and when pathogenic organisms have been reduced to a level such that the material can be handled with minimum risk.[2] Table 4.14 shows a list of initial conditions compiled from several sources.[2, 56, 74] Although these process determinants are reasonably supportable, they do not easily translate into end product characteristics. The desirable end product information listed on Table 4.14 is an attempt to summarize process objectives where, in general, aerobic decomposition is optimal. The specific testing requirements for biological toilets in Norway are: (1) no drainage of liquid from product, (2) organic matter reduction equal to or greater than 30 percent,[84] (3) fecal coliform counts less than or equal to 500 per gram of product, and (4) no unpleasant odors in toilet room. These criteria are more suitable than those described in Table 4.14 for the units under study.

**TABLE 4.14 THERMOPHILIC COMPOSTING PROCESS DETERMINANTS**

| | INITIAL CONDITIONS | DESIRED END PRODUCT |
|---|---|---|
| MOISTURE | 40%–60% | Relatively dry, no free drainage |
| OXYGEN | 5%–15% | Negligible odors or vectors |
| TEMPERATURE | 35°C | To have reached 60°C for extended periods |
| pH | 6.5–7.5 | 7–8 |
| VOLATILITY (Organic Matter) | High | Low, ash greater 50 percent, organic matter stabilized |

## 4.2 BASICS OF GREY WATER

Within the past decade, some individual home waste treatment schemes have been designed to segregate toilet or black wastes from all other wastes, grey water, generated from the household. The two waste streams can be separately collected, treated, and disposed of on site. The biological toilet discussed in Section 4.1 is a technique drawing considerable interest in water-short, sewerless, and/or remote locations. Irrespective of the technology chosen for black wastes, nearly all households produce a grey water stream. Grey water reuse appears motivated by reasons such as conservation of household wastes for return of nutrients to the soil and creation of additional water resources for water-short areas. Consumer attitude surveys have demonstrated that the public generally favors the use of reclaimed water for nonpersonal uses such as crop and golf course irrigation.[76] The public, however, was not queried about whether they would personally accept responsibility for the operation and maintenance necessary to treat the water for these uses. Apparently the public believes that grey water is fairly uncontaminated, especially when compared to black wastes, and how or where it is used or disposed of is not of much concern.[8]

Among technical circles, it is generally agreed that the quality of grey water is important for health, safety, and operational reasons.[78] Public health and safety have received the least amount of attention and operational aspects the most. Researchers tend to discuss technical and economic considerations about grey water schemes while making predictions about the recycled water's quality and microbiological content. Water quality treatment standards for grey water reuse have yet to be established; however, the National Sanitation Foundation (NSF) Standard Number 41[74] has set voluntary standards for design, construction, and laboratory performance of commercially manufactured recycle/reuse and water conservation devices. Consequently, existing grey water devices are frequently designed and marketed on the basis of consumer convenience alone.

Whether or not adequate health and safety data exists to make appropriate judgments about grey water schemes is controversial. Some authors determine the safety of grey water through philosophical deduction. For example, the argument presented by Milne:[77] ". . .if composted human feces are safe for garden use, then grey water properly managed should not be considered any more hazardous." The difficulty with this reasoning is that it is based on the nonfact that composted excrement is "safe" without a determination of what the standards for gardening use might be. Others use a more pragmatic approach by identifying some of the microbiological characteristics of actual grey water streams and making judgments about intended reuse schemes. Siegrist et al found high levels of fecal organisms in the grey water from four test homes in one study[79] and from two homes in another test[78] and concluded that grey water may routinely be contaminated by fecal matter. The authors then discussed nonbody contact reuse possibilities for toilet flushing and lawn irrigation. Another Siegrist paper[80] shows that a wide range of indicator organisms can be generated in wastewaters from bathing and clothes washing. It was concluded that grey water has the potential for containing pathogenic contaminants. The authors, however, did not propose a reuse scheme. In-home reuse for toilet flushing has not received regulatory and/or health acceptance for a variety of technical and practical reasons; however, landscape irrigation using treated community wastewater effluent is practiced in about half of the United States. Standards for irrigation reuse in areas with public access have been developed. The most conservative of these regulations, e.g., California,[81] requires a minimum of secondary treatment plus disinfection with the intent to produce a pathogen-free effluent. Secondary treatment has been defined by federal regulation as 30 mg/L of 5-day biochemical oxygen demand ($BOD_5$) and suspended solids with a pH between 6.0 and 9.0.

Grey water reuse, however, does not necessarily involve surface application of recycled waters. It could be managed so that the irrigation waters remain enclosed and subsurface by using, for example, shallow leach lines or a drip irrigation system. In this case, the recycled waters need to be consistently free of particulates that might clog irrigation or leach field pipes.

Limited studies of the past decade demonstrate that grey water has been shown to contain substantial quantities of biological, physical, and chemical contaminants. Brandes[10] found the same order of magnitude of average concentrations of total and suspended solids, $BOD_5$, TOC, and COD in both grey water and black water septic tank effluents. Average values for this grey water collected and treated by means of a septic tank unit are shown in Table 4.21. Anderson et al.[78] characterized various grey water process streams, also reported on Table 4.21, and concluded that raw grey water contains appreciable amounts of pollutants. Hathaway[9] reported the potential presence of toxic organic compounds as a result of using commerically prepared products such as deodorants and household cleaning agents. The significance of these findings remains to be determined.

The following table shows concentrations of contaminants in household generated grey water.

### TABLE 4.21 GREY WATER QUALITY–KITCHEN AND BATHROOM SINK WASTEWATERS

| PARAMETER | REFERENCES | | |
|---|---|---|---|
| | (10) Brandes | (11) Olsson | (78) Anderson |
| Total Phosphorus, mg/l | 1.4 | 7.8 | – |
| Suspended Solids, mg/l | 162 | 141 | 66 |
| BOD, mg/l | 149 | 196 | 185 |
| COD, mg/l | 366 | – | 383 |
| Total Kjeldahl Nitrogen (N), mg/l | 11.3 | 6.5 | 9.1 |
| Nitrate (N), mg/l | 0.12 | – | – |
| Electrical Conductivity ($\mu$mho/cm) | 443 | – | – |
| pH | 6.8 | – | 6.8 – 8.2 |
| Total Coliform (org/100 ml) | $24 \times 10^6$ | $3.6 \times 10^6$ | – |
| Fecal Coliform (org/100 ml) | $1.4 \times 10^6$ | $0.88 \times 10^6$ | – |

Since individual lifestyles and customs vary unpredictably, it is reasonable to expect considerable variation of the chemical and microbiological contents of household grey water.[13] It is clear that mere separation from toilet wastes does not insure personal or public safety. However, only limited information exists from research and experience with on-site treatment and reuse of household grey water. Several process schemes have been subjected to laboratory trials with promising results. Most have not been evaluated for performance reliability under field conditions. Sauer[15] demonstrated significant reductions of physical, chemical, and bacterial content by intermittent filtration of combined wastewater. Howard[16] confirmed these reductions in a laboratory setting. Based on these findings, Siegrist[12] concluded that it seems reasonable to expect at least equal and possibly higher effluent quality from a similar system treating just household wastewater. Ronayne et al[85] produced results very similar to Sauer with a field-installed recirculating sand filter in Oregon treating grey water (with the exception of lower nitrogen content).

Inadequate information on collection, treatment, and public health impacts of grey water concern health officials. Little work has been done to establish treatment standards for grey water use. Continuing work in the area of public health and water quality is necessary to produce the knowledge needed for intelligent and effective grey water use. The void in available information prompted the inclusion of existing grey water treatment sites in this study. Existing technology, both homeowner-built and proprietary units, are far different from that proposed for household use by most authors cited in this section. Units are much simpler, generally created out of necessity by the homeowner, and their performance is likewise unproven.

## 4.3 BASICS OF VECTORS

Many diverse kinds of flies, beetles, mites, and other arthropods will be attracted to fresh human excrement for feeding purposes,[16] and if the excrement accumulates in piles accessible to them, they will inhabit the pile and reproduce there.[17, 18, 19] Considerations in determining their importance to human health involve mainly whether they invade dwelling places and whether they tend to land on humans or on human food after having contact with excrement. Invasion of the dwelling place by insects and mites creates a nuisance for many people which can be stressful to them, but the actual significance of the nuisance to personal well-being depends upon the occupants' tolerance level. Of greater importance to personal and public health are excrement-frequenting arthropods which may land on humans or contaminate food after having contact with human excrement. This habit may result in the transmission of enteric disease.[20]

The arthropods of most concern in the transmission of pathogens from feces to food are a cosmopolitan group of flies called "house-invading flies,"[21] "synanthropic" or human-associated flies,[22] or domestic flies.[23] This grouping of domestic flies includes the fruit fly (Drosophilidae), the house fly (*Musca domestica*), the little house fly (*Fannia cannicularis*), the latrine fly (*Fannia scalaris*), the black garbage fly (*Ophyra spp.*), various blow flies (Calliphoridae), and flesh flies (Sarcophagidae).

Pathogenic agents of all common enteric diseases have been isolated from domestic flies,[22] and their ability to deposit those agents when they land or feed is well established.[24] How important a role flies play in spreading infection as compared with water, soil, dirty hands, or other modes depends upon the specific outbreak or local conditions.[25] The importance of the role of flies was demonstrated when the morbidity and mortality rate of *Shigella* was significantly reduced in nine towns in Texas by the application of insecticide.[41] A study of enteric disease outbreaks in Venezuela concluded that pathogens such as *Shigella* and *Salmonella* circulated partially because of flies. However, potable water quality and overall sanitation were of greater importance in reducing enteric disease in an area of very poor sanitation.[42] Flies were demonstrated responsible for transmission of *Salmonella* to a group of volunteers who consumed food which had been exposed to flies that had fed on infected dog excrement.[43] Since flies can and do transmit enteric disease to humans, the prevention of fly access to human excrement is an important aspect of the prevention of enteric disease.

Certain flies can also affect human health by direct invasion of the human body, a condition known as myiasis. Larval forms of domestic flies are responsible for many of the human cases which reach physicians in North America.[44] Susceptible individuals using a fly-infested privy carry an increased risk of contracting myiasis,[45] an invasion of cutaneous tissues by larval flies.

Various kinds of mites, especially the stored-food mite of the family Acaridae, have been associated with allergic reactions and dermatitis of humans.[46]

## 4.4 HEALTH HAZARDS ASSOCIATED WITH HOUSEHOLD WASTEWATERS

It has been well established in the literature that if a pathogenic agent or organism is excreted by an individual, it will be in his sewage whether or not techniques are refined enough for its detection. The traditional role of sewage collection and treatment is to remove this material from the immediate environment. Pathogenic agents or organisms are typically retained at the wastewater treatment plant after removal from the wastewater, and discharged back into another part of the environment or are inactivated by the disinfection process. Renewed interest in a variety of on-site waterless toilets and grey water reuse systems that keep those agents in the immediate environment warrants a review of current findings concerning pathogens, disease transfer, and health risks.

In the United States, disease hazards from household wastewaters are of the type that are not clearly recognized as such until catastrophes result from them. At least two generations have been raised in an environment relatively free of sewage-related hazards and free from the responsibility of proper treatment and disposal of their waste products. What is needed is some way of assessing the health significance and/or appropriateness of, first, the particular alternative device, and second, the ultimate disposal of residuals which may be generated by the usage of a general type of on-site system.

A review of the literature provides some appreciation for the potential health hazards associated with sewage treatment and disposal. The added occupational hazard from working with sewage in the case of wastewater treatment plant workers was reported by Dixon[26] as a slightly increased risk of exposure over the general population. Dixon further acknowledged that wastewater workers as a group appear to have a smaller risk of illness because they are in a low risk group for other diseases. Nine other publications[27] inferred from qualitative considerations that wastewater workers and/or nearby residents may be exposed to a respiratory or other disease hazard from aerosols originating at the treatment facility. Sorber et al.[28] and Dowling,[29] suggest that chronic exposure to low levels of disease organisms by these two groups results in a degree of immunity, but sporadic exposure of other populations may result in adverse health effects. Katzenelson, et al.,[30] reported that the risk of communicable disease to workers associated with wastewater irrigation in agricultural communal settlements is two to four times higher than in agricultural settlements not practicing wastewater irrigation.

It does appear that a hazard exists and that the hazard is directly correlated with the proximity of the individual to the wastewater source. According to Cooke,[31] the importance of the use of sewage contaminated waters in growing vegetables as the source of sporadic cases of infection is difficult to assess, since there are probably a number of other routes such as personal hygiene by which pathogens in household sewage may, on occasion, cause disease. The disease hazard is a complex one since more than the presence of a pathogen in dry toilet solids or grey water is needed to cause disease. According to both Bryan[32] and Dixon,[26] infective dose and a susceptible individual are both necessary if illness is to result. Dixon further noted that many disease outbreaks have resulted from the indirect ingestion of feces through contaminated water. Eighteen cases of disease transmitted by foods contaminated by human excrement and/or residuals from an individual on-site system are shown in Table 4.41.[32] Six of the cases cited show fish and animal as the vehicle as well as twelve cases of vegetable crop contaminated by bacterial, parasitic, and viral organisms.

Some evidence exists about the spread of organisms from the environment to humans. Foods can become contaminated during production in the field as well as during preparation in the home. Where contamination occurs depends on the sources of pathogens and the opportunity for transfer onto the food chain. Some parasites, for example, penetrate the human skin and may be acquired by agricultural or aquacultural workers who work in wastewater-contaminated fields. Other organisms can be brought into the home via skin and clothing. Flies are also known to be vehicles for the transport of enteric pathogens about the environment and to human food.[38, 39, 40] Organisms can be transferred from the bowel of an individual to food after contamination of the hands at the time of defecation. A great deal of attention is paid to encouraging food-handlers and others to wash their hands after using the toilet. Undoubtedly hands can become contaminated. However, handling raw meats and vegetables may result in a more important source of hand contamination. Education about hand-washing after handling raw food is equally important. Transmission via hands to food in which the organisms multiply does appear to be a likely route in many outbreaks of infection.[31] Diseases and causative agents transmissible by food that has been contaminated by wastewater or by soil that contains fecal material is shown in Table 4.42.[32]

**TABLE 4.41 OUTBREAKS ASSOCIATED WITH FOODS CONTAMINATED BY HUMAN EXCREMENT**

| DISEASE | SOURCE OF CONTAMINATION | FOOD | REFERENCE |
|---|---|---|---|
| Typhoid fever | Human manure | Rhubarb | Pixley, C., 1913 |
| Typhoid fever | Privy | Watercress | Philadelphia Bur. Health, 1913 |
| Typhoid fever, gastroenteritis | Privy-polluted water | Oysters | Ramsey, 1928 |
| Typhoid fever | Privies, raw sewage | Oysters | Old and Gill, 1940 |
| Amebiases | Night soil | Vegetables | Aldridge, 1947 |
| Typhoid fever | Night soil | Vegetables | Viehl, 1950 |
| Ascariases | Night soil | Vegetables | Anders, 1952 |
| Typhoid fever | Human manure | Endive | Harmsen, 1954 |
| Typhoid fever | Human manure | Raw salad greens | Harmsen, 1954 |
| Typhoid fever | Night soil | Vegetables | Kreuz, 1955 |
| Ascariases | Night soil | Vegetables | Kreuz, 1955 |
| Ascariases | Night soil | Vegetables | Mochmann, 1955 |
| Viral hepatitis | Septic tank discharge | Clams | Rindge, et al, 1961 |
| Taeniasis | Human feces in trench silo | Beef | Cannon, 1968; Peavy, 1968 |
| Viral hepatitis, gastroenteritis | Cesspool | Clams | Dismukes, et al, 1969 |
| Viral hepatitis | Septic tank effluent | Watercress | Hutcheson, 1971 |
| Salmonellosis | Human sewage on grazing land | Grass | Bicknell, 1972 |
| Cholera | Raw sewage irrigation | Vegetables | WHO, 1973 |
| Poliomyelitis[30] | Sewage irrigation | Cucumbers | Katzenelson, 1976 |

## TABLE 4.42 DISEASES AND CAUSATIVE AGENTS TRANSMISSIBLE BY FECALLY CONTAMINATED FOOD

| DISEASE | AGENT |
|---|---|
| **BACTERIA** | |
| Arizona infection | *Arizona hinshawii* |
| Bacillus cereus gastroenteritis | *Bacillus cereus* |
| Cholera | *Vibrio cholerae* |
| Clostridium perfringens gastroenteritis | *Clostridium perfringens* |
| Enteropathogenic Escherichia coli infection | *Escherichia coli* (certain serotypes) |
| Paratyphoid fever | *Salmonella paratyphi A*<br>*Salmonella paratyphi B*<br>*Salmonella paratyphi C*<br>*Salmonella sendai* |
| Pseudotuberculosis | *Pasteurella pseudotuberculois* |
| Salmonellosis | *Salmonella* (over 1500 serotypes) |
| Shigellosis | *Shigella sonnei*<br>*Shigella flexneri*<br>*Shigella dysenteriae*<br>*Shigella boydii* |
| Typhoid fever | *Salmonella typhi* |
| Yersinia gastroenteritis | *Yersinia enterocolitica* |
| **VIRUSES** | |
| Adenovirus infection | Adenoviruses |
| Coxsackie infection | Coxsackie viruses |
| ECHO virus infection | ECHO viruses |
| Poliomyelitis | Polioviruses |
| Reovirus infection | Reoviruses |
| Viral hepatitis | Hepatitis virus A |
| Winter vomiting disease | Norwalk agent |
| **HELMINTHS** | |
| Ascariasis | *Ascaris lumbricoides* |
| Trichiniasis | *Trichuris trichiura* |
| **PROTOZOA** | |
| Amebiasis | *Entamoeba histolytica* |
| Balantidiasis | *Balantidium coli* |
| Coccidiosis (Isospora infection) | *Isospora belli, I. hominis* |
| Giardiasis | *Giardia lamblia* |
| Dientamoeba infection | *Dientamoeba fragilis* |

## TABLE 4.43 PATHOGENIC AND OPPORTUNISTIC MICROBES IN HUMAN SEWAGE

| MICROORGANISM | DISEASE CAUSED |
|---|---|
| **Bacteria** | |
| *Salmonella spp.* | Typhoid, paratyphoid, gastroenteritis |
| *Shigella* | Bacillary dysentery |
| *Yersinia* | Gastroenteritis |
| *Mycobacteria* | Tuberculosis |
| *Leptospira* | Leptospirosis (Weils disease) |
| *Pathogenic coliform* | Gastroenteritis, urinary infections |
| **Opportunistic Bacteria** | |
| *Pseudomonas* | Respiratory and burn infections, diarrhea |
| *Klebsiella* | Pneumonia, bronchitis |
| *Serratia* | Respiratory and urinary infection |
| *Proteus* | Summer diarrhea, urinary infection |
| **Viruses** | |
| Poliovirus | Poliomyelitis |
| Hepatitis Type A | Infectious hepatitis |
| Echovirus | Respiratory disease, diarrhea, fever |
| Coxsackie A & B | Respiratory disease, fever |
| Reovirus | Gastroenteritis, respiratory disease |
| Adenovirus | Respiratory disease and eye infections |
| **Protozoa** | |
| *Entamoeba histolytica* | Amoebic dysentery |
| *Giardia lamblia* | Gastroenteritis |

The number of coliform bacteria present have been used as an index of the degree of pollution and of the possible presence or absence of pathogenic bacteria. However, in this case, no generally accepted standards are available for human waste products and household grey water which are to be used as a soil amendment or for irrigation. Generally, *Citrobacter* and *Klebsiella* organisms outlive coliform bacteria in all habitats other than the intestine and these become predominant in soil.[31] Other enteric bacteria which could conceivably be transmitted by foods, but proof is inconclusive, are: *Streptococcus faecalis, Providencia spp., Streptococcus faecium, Proteus spp., Enterobacter spp., Edwardsiella spp., Aeromonas spp., Pseudomonas aeruginosa.*[32] Adams and Lewis[33] suggest that although *Pseudomonas, Proteus, Klebsiella,* and *Serratia* are not considered highly pathogenic, literature is replete with case histories to indicate they are capable of causing a wide spectrum of disease conditions. They are most infective for the young, aged, and/or infirm. When these organisms are present in high numbers, they may be the cause for concern. This is possibly the reason for collectively labelling these organisms "opportunistic bacteria." Pathogenic and opportunistic organisms, and the diseases they can cause in susceptible individuals, are shown in Table 4.43.[33]

A small amount of available evidence suggests that there is geographical variation in the types of bacteria present in humans. However, the frequency of occurrence of bacteria other than coliform is virtually unknown, even though the human intestinal system has been studied in great detail. Bacteria isolated from the feces of normal individuals in low numbers include *Pseudomonas, Aeromonas, Klebsiella, Citrobacter,* and *Enterobacter.*[14] Various researchers have reported limited quantitative information about the fecal flora of healthy adults: 67 percent contain *Citrobacter,* 20–30 percent *Klebsiella,* and 12 percent *Pseudomonas.*[14, 34, 35] Other researchers[36] observed a higher incidence of some of these organisms in polluted waters. The relationship between the normal fecal flora and strains of organisms causing disease is not known.[31]

Although the greatest part of organic matter present in human feces is in the form of bacteria,[36] almost all agents capable of causing infectious disease in humans such as bacteria, viruses, and parasites are excreted through the intestinal tract. In view of the limitations of current knowledge about opportunistic bacteria, and lack of information about viruses and parasites, raw or untreated human waste products should be considered potentially infectious and hazardous.

## 4.5 HEALTH RISK ASSESSMENT

One of the most important aspects in considering the environmental impact of wastewater disposal and wastewater reuse is that of the effect of such activity upon the public health. Making such a judgment requires some estimate of the risk involved.

An evaluation of the health risks posed by the use of on-site waste disposal systems (Figure 4.51) requires knowledge concerning: (1) the presence of agents that cause disease, (2) the dose response characteristics of the agents involved, (3) the manner in which the agent comes into contact with susceptible individuals, and (4) the design and operation of the systems in question. Unfortunately, in many instances, data on one or more of the preceding items are not available.

The disease agents and public health problems usually associated with on-site systems are shown in Tables 4.42 and may be classified as infectious and noninfectious. The infectious agents of most importance in considering on-site disposal systems are those of intestinal origin. These would comprise three main groups, namely, bacteria, eucaryotic and multicellular parasites, and viruses. Zoonotic diseases may also be involved as a result of the mismanagement of wastewater discharge onto the land, a major characteristic of many on-site systems. The noninfectious disease agents can be further divided into two classes: toxic chemicals and nuisance conditions. A major toxic chemical associated with on-site systems is nitrate. Relative to nuisance conditions is the on-site system's potential for encouraging the breeding of insects and the production of odors.

Information on human dose response to infectious and noninfectious disease agents is limited. Some information is available on this relationship between man and certain bacterial and parasitic diseases.[4] As might be expected, the dose response varies from one agent to another. In the case of bacterial enteric disease, it usually takes a large number of organisms to elicit a significant response in challenged individuals (as few as 100 *Shigella sp.* to 1 x $10^8$ cholera vibrios to produce 25 to 75 percent response in man). In the case of parasitical diseases such as Giardiasis, the dose required to produce infection may range from 10 to 1 x $10^6$ cysts per individual exposed. At the time of this writing, there is a great deficiency in dose response data involving enteric viruses.

In order to contract a disease, the susceptible host must come into contact with an effective dose. The contact may be direct or indirect. An example of an indirect contact is that resulting from the utilization of grey water (raw or treated) for the irrigation of food plants. Another is the contact made possible through the deposition of treated or untreated fecal matter on soil, thereby providing the potential for the contamination of food with pathogens. An example of direct contact is drinking and cooking with water that has been contaminated with leachate from a poorly sited septic tank system. Obviously, the more direct the contact, the more certain it is that an effective dose will reach the host.

Another aspect of dose contact involves the density of the exposed population. Here an important consideration is the number of individual on-site systems that can function in a given locale without increasing the potential for disease transmission to an unduly high level or without the development of unacceptable aesthetic conditions.

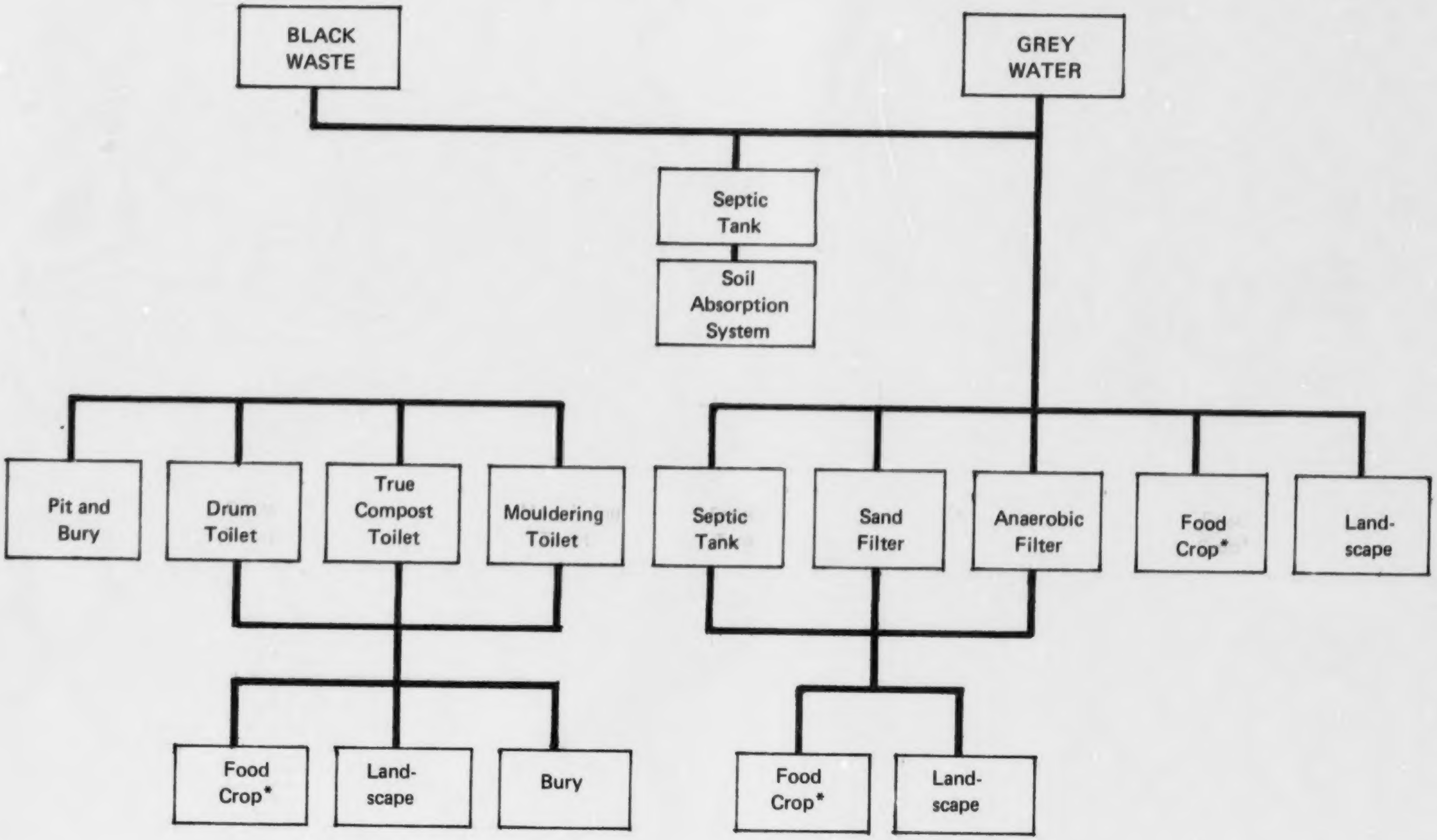
**Risk Assessment**

Risk is not an unfamiliar concept as all of us are constantly subject to an array of risks during our daily lives. However, quantitating these risks is frequently considered impractical because of lack of adequate data.

The term risk as used in this report is defined as a compound measure describing the probability of an adverse event occurring and the severity in such an advent. Risk assessment involves the process of making estimates that particular adverse events will occur in a given time period, while risk evaluation involves a social value judgment as to what level of risk is acceptable.

Kates[82] has defined three methods used in estimating risk: revelation, intuition, and extrapolation. Revelation and intuition, though frequently applied, are generally not accepted as scientific because of their reliance on conjecture and implicit judgment. The last method, extrapolation, involves the extending or projection of known information about a specific event in order to estimate some other event. Moreau[83] has further defined extrapolation to include the following methods: (1) standard statistical methodology, (2) causal models based on known phenomenological relationships, and (3) formal methods of encoding expert opinion in the form of judgmental probabilities. Environmental data required by the first two methods of risk assessment frequently do not exist or are not readily available. In real situations, however, decisions by a responsible agency must be made. This report deals with an application of the third method cited above to the risk assessment of waste disposal alternatives.

The public health implications of various wastewater treatment activities have generally been described in terms of the variety of chemical and biological agents that might be present. In some cases, direct or indirect measure of the concentration of these agents is available. As a rule, implicit judgments of risk are made from such information with the end product expressed as the situation being good or bad. The Health Evaluation Committee was interested in exploring a more explicit judgment technique. The method adopted was a probability matrix technique. With this method, effective utilization is made of the expertise of public health specialists in arriving at explicit judgments regarding the relative health risk in the application of a given on-site system. The on-site systems evaluated using this technique are shown in Figure 4.51 and described in Appendix B. It should be noted that this evaluation included a device called a "true compost" toilet, which is defined in Appendix B-3. No such unit exists in the field portion of this study, but it was conceived as an "ultimate" biological toilet for the purposes of this evaluation.


BLACK WASTE
GREY WATER
Septic Tank
Soil Absorption System
Pit and Bury
Drum Toilet
True Compost Toilet
Mouldering Toilet
Septic Tank
Sand Filter
Anaerobic Filter
Food Crop*
Land-scape
Food Crop*
Land-scape
Bury
Food Crop*
Land-scape

* Rooted or leafy crops intended for human consumption.

FIGURE 4.51 ON-SITE WASTE DISPOSAL SYSTEMS

## The Probability Matrix Technique

The probability matrix technique (PMT) risk assessment method requires the input of two groups of health experts. The first group delineates health problems which may be associated with a given process and estimates the probability of their occurrence. The role of the second group is to judge the severity of the problems delineated by the first group. Members of the first group are instructed to make judgments on the probability of problem occurrence and to place a value on the probability using a linear scale of zero to one. In such a scale, values less than 0.5 indicate that the occurrence of a problem is less likely than its nonoccurrence.

A public health problem is defined as a situation in which the incidence of disease or level of annoyance increases above background to the degree that action by a health agency would be indicated.

Members of the second group are directed to make judgments concerning the severity of the problems named by the first group. Relative severity is ranked from 0 to 100, with 100 being the most severe and 0 the least. If necessary, the same value can be associated with more than one problem. In this instance, the severity of a problem must be considered in terms of the impact of a given disease agent or environmental factor on the health of an individual who has contracted said disease or disability. Relative judgments as to the severity of a problem are in comparison to the other problems being considered and not to some absolute level of severity. The severity judgments are medical opinions based on collective knowledge of the life expectancy, degree of disability, and effectiveness of treatment of the public health problems considered. The membership of the first group includes experts in bacteriology, virology, parasitology, entomology, sanitary engineering, and similar professions. The second group of experts is composed of physicians.

From the judgments made by the two groups of experts, an estimate of the magnitude of the risk of a health problem related to a particular on-site system can be determined. The calculation of the magnitude of the risk is as follows:

$$r_i = \frac{\sum_{j=1}^{n} P_{ij} S_j}{\sum_{j=1}^{n} S_j} \qquad (1)$$

where $r_i$ is the incremental magnitude of risk (0–1), $P_{ij}$ is the subjective probability of a problem, j will occur under condition $i (0 \leq p_{ij} \leq 1)$, $S_j$ is the relative severity of problem j $(0 \leq S_j \leq 100)$, n is the number of public health problems (j) being evaluated.

The assessment method employs two steps in arriving at estimates of the public health risk of the systems involved. The process previously described was used (see equation 1). The $r_i$ value is determined for each type of alternative system under various environments/conditions. A second step is included in which a series of r values are determined for the system under various conditions of climate, depth of ground water, soil percolation times, depth to bedrock, land slope, and population density (see Appendix B definitions). This second step combines the incremental risk estimates:

$$R = r_1 \times r_2 \times r_3 \times r_4 \times r_5 \times r_6 \qquad (2)$$

where R is the probability of a public health problem over the life of a system. The concept of Fault-tree analysis[86, 87] was used, in part, to develop the risk assessment approach. As with Fault-tree analysis, the above approach follows a comprehensive and ordered method of reducing some undesirable event (public health problem) into its various causes (incremental risks) and displaying them in a logical format. The key assumption of independence then allows the incremental risk values to be multiplied to calculate the total risk value.

The key assumption made in using these risk equations is that the P values and incremental risk values act independently. In actuality, such an assumption may not be true; however, if the problem and environmental condition categories are judiciously taken and grouped, the assumption may become more acceptable. A consequence of the independence assumption is that the net probabilities can be obtained rather easily. The process requires the development of a matrix which produces the estimated $r_i$ value for each type of system or system combinations under the selected conditions. An example of such a matrix is shown in Table 4.51. The 20 health problems to be considered are listed as a heading of this table.

**TABLE 4.51 EXAMPLE OF A PROBABILITY MATRIX TO ESTIMATE THE $r_i$ VALUES FOR A GIVEN DISPOSAL SYSTEM UNDER A VARIETY OF CONDITIONS**

**(See Appendix B for condition definitions)**

| **SEVERITY ($S_j$)** | | | | | | | | | | | | | | | | | | | | | $r_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PROBLEM $j$**<br>**CONDITION $i$** | **Enteric Viruses** | **Polioviruses** | **Infectious Hepatitis** | **Encephalitis** | **Typhoid** | ***Salmonella*** | ***Shigella*** | ***Ascaris*** | **Hookworm** | ***Giardia*** | ***Entamoeba Histolytica*** | **Cestodes** | **Animal Parasites** | **Beetles** | **Rodents** | **Flies and Gnats** | **Mosquitoes** | **Venomous Arthropods** | **Odors** | **Nitrates** | **Risk** |
| **Climate:** | | | | | | | | | | | | | | | | | | | | | |
| Mountain | | | | | | | | | | | | | | | | | | | | | |
| Desert | | | | | | | | | | | | | | | | | | | | | |
| Coastal | | | | | | | | | | | | | | | | | | | | | |
| **Groundwater:** | | | | | | | | | | | | | | | | | | | | | |
| < 3 feet | | | | | | | | | | | | | | | | | | | | | |
| 3–5 feet | | | | | | | | | | | | | | | | | | | | | |
| > 5 feet | | | | | | | | | | | | | | | | | | | | | |
| **Soil Percolation:** | | | | | | | | | | | | | | | | | | | | | |
| faster than 45 $\frac{\text{min.}}{\text{in.}}$ | | | | | | | | | | | | | | | | | | | | | |
| 45–60 | | | | | | | | | | | | | | | | | | | | | |
| slower than 60 | | | | | | | | | | | | | | | | | | | | | |
| **Depth to Bedrock:** | | | | | | | | | | | | | | | | | | | | | |
| < 4 feet | | | | | | | | | | | | | | | | | | | | | |
| > 4 feet | | | | | | | | | | | | | | | | | | | | | |
| **Topography Slope:** | | | | | | | | | | | | | | | | | | | | | |
| 0–10 percent | | | | | | | | | | | | | | | | | | | | | |
| 11–30 percent | | | | | | | | | | | | | | | | | | | | | |
| > 30 percent | | | | | | | | | | | | | | | | | | | | | |
| **Density:** | | | | | | | | | | | | | | | | | | | | | |
| Low–A | | | | | | | | | | | | | | | | | | | | | |
| Low–B | | | | | | | | | | | | | | | | | | | | | |
| Medium–A | | | | | | | | | | | | | | | | | | | | | |
| Medium–B | | | | | | | | | | | | | | | | | | | | | |
| High–A | | | | | | | | | | | | | | | | | | | | | |
| High–B | | | | | | | | | | | | | | | | | | | | | |

## Risk Assessment Results

An outside committee of professionals (Appendix B) was convened in order to assess the probability of a problem occurring ($p_{ij}$) for each type of on-site system. This group was called the Health Evaluation Committee. A second group of five public health physicians developed estimates of problem severity ($S_j$).

As shown in Figure 4.52, implementation of the risk assessment technique followed two lines of investigation. A general risk assessment was conducted based on literature and hypothetical conditions followed by a site-specific risk assessment based on the results of the field studies.

The general risk assessment investigation utilized the Delphi technique to obtain estimates of the probability of the occurrence of a problem ($P_{ij}$). This technique is a method of applying the collective knowledge or abilities of a diverse group of experts to the task of quantifying variables that either are intangible or are shrouded in uncertainty. The term "expert," as defined by the developers of the technique (Rand Corporation), generally implies a highly educated and experienced specialist.

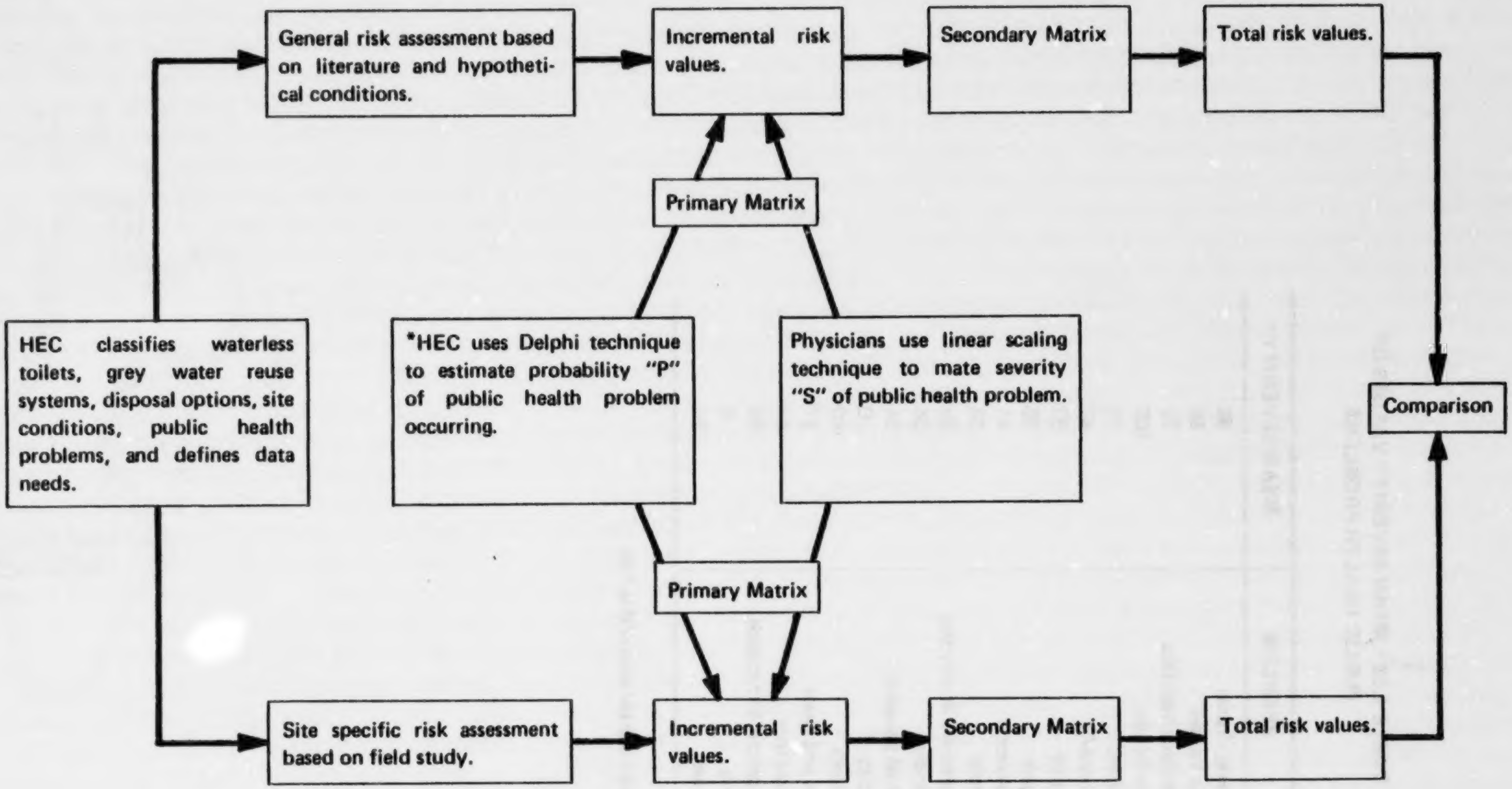
The Delphi technique involves the use of a series of questionnaires designed to produce group consensus and to eliminate face-to-face confrontation as is experienced in panels or committees. The key characteristics of the Delphi approach are anonymity, controlled feedback, and statistical group response. Anonymity is attained through the use of questionnaires. In this way, the effect of an undue influence of dominant panel members upon the responses of other panel members is avoided. Controlled feedback is attained by conducting the exercise in a sequence of rounds, between each of which a summary of the results of the previous round is communicated to the participants. The effect is a reduction in "noise." Use of the statistical group response reduces group pressure for conformity and assures that the opinion of every member is represented in the final response.

During the first round, the committee members were requested to provide estimates of $P_{ij}$ for only those combinations of problems and conditions for which they felt qualified to estimate values. During the second round, a statistical summary of the first round was returned to each participant; and if any changes in their original estimate were desired, such changes could be made. The majority of the members believed their estimates and made no changes. When changes were made by an individual, they were prompted by a desire either to adjust to the group mean or by the feeling that other group members knew more about the problem. The mean values of $P_{ij}$ were then recalculated.

The severity values were solicited from the five public health physicians. The values were developed on a linear scale of 0 to 100 as previously described. The derived mean values of the public health problem severity ($S_j$) are shown in Table 4.52.

Following equation 1, the incremental risk values were calculated using the mean of $P_{ij}$ values obtained in the second Delphi round and the mean $S_j$ values of Table 4.52. These incremental ($r_i$) values for all the disposal systems considered and for each condition are shown in Table 4.53. In all cases the incremental risk was assessed to be below 0.5, indicating greater probability under a specific environmental condition of nonoccurrence than occurrence. Using the results shown in Table 4.53 and following equation 2, an estimate of the total system risk can be obtained. The results of the total risk (R) for a number of systems under similar conditions are shown in Table 4.54.

Estimates of the public health risk of combined black waste and grey water disposal systems are shown in Table 4.55. These estimates were made by calculating the composite event of the probability of a problem occurring when both systems are operative. Because risk values are for a single technology installation, an increased number of installations will constitute an increased risk, i.e., the risk is additive.


HEC classifies waterless toilets, grey water reuse systems, disposal options, site conditions, public health problems, and defines data needs.
General risk assessment based on literature and hypothetical conditions.
Incremental risk values.
Secondary Matrix
Total risk values.
Primary Matrix
*HEC uses Delphi technique to estimate probability "P" of public health problem occurring.
Physicians use linear scaling technique to mate severity "S" of public health problem.
Comparison
Primary Matrix
Site specific risk assessment based on field study.
Incremental risk values.
Secondary Matrix
Total risk values.

* The Delphi technique was not used by the HEC in the site specific risk assessment.

FIGURE 4.52 PROBABILITY MATRIX TECHNIQUE

## TABLE 4.52 MEAN SEVERITY VALUES OF PUBLIC HEALTH PROBLEMS

| PROBLEM | MEAN SEVERITY* |
|---|---|
| Enteric virus infection | 58 |
| Poliomyelitis | 89 |
| Infectious hepatitis | 79 |
| Encephalitis | 100 |
| Typhoid | 72 |
| *Salmonellosis* | 47 |
| *Shigellosis* | 53 |
| *Ascaris* | 25 |
| Hookworm | 41 |
| *Giardiasis* | 36 |
| Amoebic dysentery | 59 |
| Cestode infection | 36 |
| Animal parasites | 24 |
| Beetles | 0 |
| Rodents | 40 |
| Flies and gnats | 37 |
| Mosquitoes | 47 |
| Venomous arthropods | 66 |
| Odors | 9 |
| Nitrates | 44 |

* Relative linear scale of 0 to 100.

## TABLE 4.53 INCREMENTAL RISK VALUES FOR SYSTEM OPTIONS

| CONDITION<br>i | Pit and Bury | Drum Toilet to Food Crop | Drum Toilet to Landscape | Drum Toilet and Bury | True Compost to Food Crop | True Compost to Landscape | True Compost and Bury | Mouldering Toilet to Food Crop | Mouldering Toilet to Landscape | Mouldering Toilet and Bury | Septic Tank—Soil Absorption System | Grey Water to Septic Tank to Land | Grey Water to Septic Tank to Food Crop | Grey Water to Sand Filter to Landscape | Grey Water to Sand Filter to Food Crop | Grey Water to Anaerobic Filter to Landscape | Grey Water to Anaerobic Filter to Food Crop | Grey Water to Food Crop | Grey Water to Landscape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Climate:** | | | | | | | | | | | | | | | | | | | |
| Mountain | .3 | .4 | .3 | .2 | .3 | .2 | .1 | .4 | .3 | .2 | .2 | .2 | .2 | .3 | .2 | .3 | .2 | .3 | .2 |
| Desert | .3 | .4 | .3 | .2 | .3 | .1 | .1 | .3 | .2 | .1 | .1 | .1 | .2 | .2 | .1 | .2 | .2 | .3 | .2 |
| Coastal | .3 | .4 | .3 | .2 | .3 | .2 | .1 | .4 | .3 | .2 | .2 | .2 | .3 | .3 | .2 | .3 | .2 | .3 | .2 |
| **Groundwater** (assume potable water): | | | | | | | | | | | | | | | | | | | |
| < 3 feet | .4 | .3 | .2 | .3 | .2 | .2 | .2 | .3 | .2 | .2 | .3 | .2 | .3 | .3 | .2 | .2 | .2 | .3 | .2 |
| 3–5 feet | .3 | .2 | .2 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 |
| > 5 feet | .2 | .2 | .1 | .1 | .1 | .1 | .1 | .2 | .1 | .1 | .1 | .1 | .2 | .2 | .1 | .2 | .1 | .2 | .1 |
| **Soil Percolation:** | | | | | | | | | | | | | | | | | | | |
| faster than 45 $\frac{\text{min.}}{\text{in.}}$ | .3 | .2 | .2 | .2 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .1 | .2 | .2 | .2 | .2 |
| 45–60 | .2 | .2 | .2 | .2 | .2 | .1 | .1 | .2 | .2 | .1 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 |
| slower than 60 | .2 | .2 | .2 | .2 | .2 | .1 | .1 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .3 | .2 |
| **Depth to Bedrock:** | | | | | | | | | | | | | | | | | | | |
| < 4 feet | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .3 | .2 |
| > 4 feet | .2 | .2 | .2 | .1 | .2 | .1 | .1 | .2 | .2 | .1 | .1 | .1 | .2 | .2 | .1 | .2 | .1 | .2 | .2 |
| **Topography Slope:** | | | | | | | | | | | | | | | | | | | |
| 0–10 percent | .2 | .3 | .2 | .2 | .2 | .1 | .1 | .2 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 |
| 11–30 percent | .2 | .3 | .2 | .1 | .2 | .1 | .1 | .3 | .2 | .1 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 |
| > 30 percent | .3 | .3 | .2 | .2 | .2 | .2 | .1 | .3 | .2 | .2 | .3 | .2 | .1 | .2 | .2 | .2 | .2 | .2 | .2 |
| **Density:** | | | | | | | | | | | | | | | | | | | |
| Low–A | .2 | .3 | .2 | .1 | .2 | .1 | .1 | .3 | .2 | .1 | .1 | .1 | .2 | .2 | .1 | .2 | .1 | .2 | .2 |
| Low–B | .2 | .3 | .2 | .1 | .2 | .1 | .1 | .3 | .2 | .1 | .1 | .1 | .2 | .2 | .1 | .2 | .1 | .2 | .2 |
| Medium–A | .3 | .3 | .3 | .1 | .2 | .2 | .1 | .3 | .2 | .1 | .1 | .2 | .2 | .2 | .2 | .2 | .2 | .3 | .2 |
| Medium–B | .3 | .4 | .3 | .2 | .3 | .2 | .1 | .3 | .3 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .2 | .3 | .2 |
| High–A | .3 | .4 | .3 | .2 | .3 | .2 | .2 | .4 | .3 | .2 | .2 | .2 | .3 | .3 | .2 | .3 | .3 | .3 | .2 |
| High–B | .4 | .4 | .4 | .3 | .3 | .3 | .2 | .4 | .3 | .3 | .2 | .2 | .3 | .3 | .2 | .3 | .3 | .3 | .3 |

### TABLE 4.54 INCREMENTAL AND TOTAL SYSTEM RISK VALUES FOR DISPOSAL SYSTEMS UNDER SAME CONDITIONS (BLACK WASTE)

| SYSTEM | CONDITION | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coastal | Groundwater > 5 Feet | Soil Percolation 45–60 $\frac{\text{Min.}}{\text{In.}}$ | Depth to Bedrock: < 4 Feet | Slope 11–30 Percent | Density: Medium (A)[1] | Total System Risk R Probability of a Public Health Problem/System Life | Probability of Public Health Problem During System Life[2] |
| Septic Tank Soil Absorption System | .2 | .1 | .1 | .1 | .1 | .1 | $2 \times 10^{-6}$ | 1:500,000 |
| Mouldering Toilet to Landscape | .3 | .1 | .2 | .2 | .2 | .2 | $4.8 \times 10^{-5}$ | 1:21,000 |
| Mouldering Toilet to Food Crop | .4 | .2 | .2 | .2 | .3 | .3 | $2.9 \times 10^{-4}$ | 1:3,500 |
| Drum Toilet to Landscape | .3 | .1 | .2 | .2 | .2 | .3 | $7.2 \times 10^{-5}$ | 1:14,000 |
| Drum Toilet to Food Crop | .4 | .2 | .2 | .2 | .3 | .3 | $2.9 \times 10^{-4}$ | 1:3,500 |
| True Compost to Landscape | .2 | .1 | .1 | .1 | .1 | .2 | $4 \times 10^{-6}$ | 1:250,000 |
| True Compost to Food Crop | .3 | .3 | .2 | .2 | .2 | .2 | $4.8 \times 10^{-5}$ | 1:21,000 |
| Grey Water to Landscape | .2 | .1 | .2 | .2 | .2 | .3 | $3.2 \times 10^{-5}$ | 1:31,000 |
| Grey Water to Food Crop | .3 | .2 | .2 | .2 | .2 | .3 | $1.4 \times 10^{-4}$ | 1:7,100 |
| Grey Water to Sand Filter to Landscape | .2 | .1 | .2 | .2 | .2 | .2 | $3.2 \times 10^{-5}$ | 1:31,000 |
| Grey Water to Sand Filter to Food Crop | .3 | .2 | .2 | .2 | .2 | .2 | $9.6 \times 10^{-5}$ | 1:10,500 |
| Pit Privy | .3 | .2 | .2 | .2 | .2 | .3 | $1.4 \times 10^{-4}$ | 1:7,100 |
| True Compost, Mouldering Toilet, and Drum Toilet to Bury | .2 | .1 | .1 | .1 | .1 | .1 | $2 \times 10^{-6}$ | 1:500,000 |

[1] Density: Medium (A) is defined as less than 20 systems, 1–5 acres per system, normal population distribution, and 2.5 persons per system.

[2] This value equals 1/R, e.g., $R = 2 \times 10^{-6}$, chance of public health problem occurring during system life is equal to $1/2 \times 10^{-6} = 5 \times 10^{5}$ or 1 chance in 500,000 (1:500,000).

## TABLE 4.55 ESTIMATE OF HEALTH RISK IN THE COMBINED DISPOSAL OF BLACK WASTE AND GREY WATER[1]

| BLACK WASTE SYSTEM | COMBINED RISK ESTIMATE[2, 3, 4] | |
|---|---|---|
| | Raw Grey Water to Landscape | Raw Grey Water to Food Crop |
| Septic Tank Soil Absorption System | $2 \times 10^{-6}$ (1:500,000) | |
| True Compost, Mouldering, and Drum Toilet to Bury | $3.4 \times 10^{-5}$ (1:30,000) | $1.4 \times 10^{-4}$ (1:7,100) |
| True Compost to Landscape | $3.6 \times 10^{-5}$ (1:28,000) | $1.4 \times 10^{-4}$ (1:7,100) |
| Mouldering Toilet to Landscape | $8 \times 10^{-5}$ (1:12,500) | $1.9 \times 10^{-4}$ (1:5,300) |
| True Compost to Food Crop | $8 \times 10^{-5}$ (1:12,500) | $1.9 \times 10^{-4}$ (1:5,300) |
| Drum Toilet to Landscape | $1 \times 10^{-4}$ (1:10,000) | $2.1 \times 10^{-4}$ (1:4,800) |
| Pit Privy | $1.7 \times 10^{-4}$ (1:5,900) | $2.8 \times 10^{-4}$ (1:3,600) |
| Mouldering Toilet to Food Crop | $3.2 \times 10^{-4}$ (1:3,100) | $4.3 \times 10^{-4}$ (1:2,300) |
| Drum Toilet to Food Crop | $3.2 \times 10^{-4}$ (1:3,100) | $4.3 \times 10^{-4}$ (1:2,300) |

1 Composite event of probability of a public health problem occurring with the black waste system or with the grey water system (i.e., p(A or B) = p(A) + p(B) – p(AB) where A and B represent the black and grey water systems respectively.

2 Probability of a public health problem occurring per system life.

3 Chance of public health problem occurring during system life is shown in parentheses.

4 Based on environmental conditions set forth in Table 4.54.

The results of the general risk assessment as shown in Table 4.54 indicate that all dry toilets which utilize waste disposal through burying of the solids are estimated to present the same degree of risk (even though the handling risk would vary with the toilet) and said risk is the same as that encountered with the septic tank soil absorption system. Basically, the calculated risk of $2 \times 10^{-6}$ indicates that there is 1 chance in 500,000 that a public health problem will occur during the system life for these systems.

Disposal of waste from the mouldering and drum toilets to food crops is estimated to have a risk of 1 chance in 3,500 of occurring during this system life. This risk is approximately 145 times greater (500,000/3,500 = 145) than the risk presented by burying the solids or the risk of the septic tank soil absorption system. Disposal of wastes from a "true composting" toilet to food crop, however, would present a risk of 1 chance in 21,000 of occurring during the system life which is approximately 24 times (500,000/21,000 = 24) greater than the risk presented by burying or the risk of the septic tank-soil absorption system. The use of mouldering and drum toilets with solids disposal to food crops is estimated to be 6 times (21,000/3,500 = 6) the risk value of the use of the "true compost" toilet with disposal to food crops. Raw grey water disposed onto food crops has an estimated risk value of 4 times (31,000/7,000 = 70) that of the septic tank system and dry toilets with disposal of the solids by burying. Review of Table 4.54 indicates that grey water treated through the sand filters used in this study before disposal presented roughly the same risks as those of untreated grey water.

An estimate of the public health risk of combined black waste from dry toilets and grey water systems (see Table 4.55) indicates a 17- (500,000/30,000 = 17) to-217- (500,000/2,300 = 217) fold greater risk than that attending the use of a septic tank system. One must, however, recognize that these risks range from 1 chance in 500,000 to 1 chance in 2,300 of occurring over the life of the system. Also, the dry toilet risks were increased, in some cases, by an order of magnitude by combining them with the risks associated with grey water disposed to landscaping or food crops. The combined risk of the dry toilet with burial of the black waste and subsurface grey water disposal would be equivalent to that of the septic tank system. The results of the site-specific risk assessment were similar to the general risk assessment; therefore, it was the consensus of the Health Evaluation Committee that the general risk assessment adequately represented their opinion.

The health risk assessment technique brought out several factors that were important in affecting risk judgment. These factors included the disposal system conditions, end product disposal, system maintenance, and disease morbidity in the associated population.

The disposal system conditions of climate and population density play a predominant role in the determination of estimated risk values. Climate was considered a major variable since conditions of temperature, rainfall, and sunlight have a significant impact upon the survival and transport of disease agents that might be present in black waste or grey water. A desert climate was associated with the least risk, while mountains and coastal climates were felt to constitute a somewhat greater hazard. From the list of incremental risks shown in Table 4.51, it can be seen that the risk estimate tended to double when the system use conditions changed from low to high population density.

The degree of risk, as shown by these estimates, is heavily dependent upon the final use (disposal) of the black waste and grey water. As one might suspect, risk estimates increased in the following order: bury $<$ landscape $<$ food crop. This obviously reflects the experts' judgment concerning the mode of dose contact.

In making health risk estimates, the group of experts assumed that the on-site systems would be properly maintained. Thus, this factor was not a variable included as a system condition. The group felt that the impact of poor maintenance would have a minor effect on public health risk values as long as systems were used in lightly populated areas. This means that improper maintenance may increase the risk to the individual involved in such maintenance activity, but the development of a public health problem as defined would most likely not occur.

The health risks associated with on-site waste treatment and disposal systems will vary with the disease morbidity in associated populations. Reported enteric infectious disease morbidity in the United States is generally low and, consequently, agent doses are low and dose contact limited. Thus, documented disease incidents associated with on-site systems are relatively rare events. Conditions outside the United States may be very different, especially in less developed and highly populated countries. Therefore, the values generated by this present exercise would not universally apply.

Based on the above risk assessment results, a representative sampling plan was developed and a larger representative sample of experts submitted $P_{ij}$ and $S_{ij}$ estimates establishing a more comprehensive estimate of risk. Overall 42 group 1 experts and 428 out of 2,500 group 2 experts (physicians) submitted $P_{ij}$ and $S_{ij}$ estimates. The results of the additional work are contained in Appendix B.

**Summary and Conclusions**

Frequently judgment concerning the health risk associated with wastewater disposal alternatives must be made with an insufficiency of data. The risks assessment approach described herein is highly conducive to the formation of insights into the public health implications of disposal alternatives. The assessment method renders explicit the judgment of experts by recording the information used by them and the risk probability value assigned to a particular activity for the decision-maker's review. The methodology used is certainly subject to improvement. The risk values developed are by no means absolute probabilities but can serve as a useful tool in community planning and governmental review. The exercise tends to place potential health problems into a proper perspective and give one a sense of their magnitude.

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# SECTION 5
# METHODS IN FIELD AND LABORATORY

## 5.1 SITE AND UNIT SELECTION

The waterless toilet units selected for inclusion in the study were of seven general types: pit privy, vault privy, 55-gallon drum privy, large sloped fiberglass toilet, large sloped plastic toilet, small box-like toilet with topping bar, and small box-like toilet with rotor.

The first three types are designed to be built in place by the homeowner/builder and are usually located apart from the living quarters. The latter four are usually factory-made. Appendix A provides a more detailed description of each site, general user information, and a summary of known operation and maintenance schedules for each unit.

The grey water systems examined in the study included grey water septic tank and proprietary settling tank—leach field units, single and multi-media filters, and no treatment.

The Office of Appropriate Technology (OAT) was primarily responsible for the site selection process. OAT'S function is to assist and advise the Governor and to encourage state agencies to develop and implement less costly and less energy-intensive technologies and programs in the areas of recycling, waste disposal, agriculture, building design, and energy and water conservation. The actual site selection process began in February 1978 when all local directors of environmental health in California's 58 counties were contacted by letter from OAT and invited to participate. Twelve counties expressed interest in participating, systems were selected in ten counties, and monitoring completed in the following eight: Calaveras, Humboldt, Kern, Marin, Mendocino, Monterey, Nevada, and Sonoma. An effort was made to obtain representative systems in as many varying environmental and physical situations as possible, but all sites and units were to meet the following criteria:

1. Units were officially recognized and in compliance with existing local requirements of county health departments and/or local regulatory bodies.
2. Units were slated for year-round use.
3. Occupants were willing to allow a year of unit monitoring.
4. County health officials and site owners were in agreement on the liability and confidentiality of the study.

The units selected under these criteria were subject to monthly visits by the field staff who were either county health sanitarians or Department of Health Services project staff. As the study progressed, the number of units monitored monthly varied. This variation was due to different reasons including inaccessibility of sites (especially during winter months), site owners deciding to drop out of the study, occupants not being present on the day of inspection, inconsistent or seasonal use of units by the occupants, discontinuation of use of units during change of occupants, or field investigator failure to perform. Except for two sites noted on Table 5.10, all systems were essentially in continuous operation throughout the study.

Early into the data phase, additional existing or newly installed units were considered for inclusion. As noted on Table 5.10, the most rigorous sampling took place between August 1979 through June 1980 when laboratory services were available to the project. Six units in Marin County were added in August 1979, and another three units in Calaveras County were added in November 1979. The type of laboratory work ordered for each site was predetermined in an effort to develop information about all system types. The results of analytical work were generally not

## TABLE 5.10 WATERLESS TOILETS
## SUMMARY OF FIELD AND LABORATORY DATA COLLECTION
## FEBRUARY 1979–JUNE 1980

| SYSTEM | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | OX | OXo | OXo | OXo | | | OXoΔ | OXoΔ | OXoΔ | | | OXoΔ⊳ | | Discon. | | | |
| Q | O | OXo | OXo | OXo | | | OXoΔ | OXo | OXoΔ | OXoΔ | OXoΔ⊳ | OXoΔ⊳ | OXo | OΔ⊳ | O | OoΔ | OoΔ |
| X | | | OX | Oo | OXΔ | OXo | | | OΔ | Discontinued for winter | | | | | | | |
| G | | | | | | | | | | OXo | OXo | OXo | OXo | OXo | OXo | OXoΔ | OXo |
| H | | | | | | | | | | Oo | Oo | Oo | OoΔ | OXo | OXo | OXoΔ | OXo |
| A | | | O | Oo | Oo | Oo | OXoΔ | OXoΔ | OXo | OXoΔ⊳ | OXo | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OΔ⊳ | OXoΔ | OoΔ⊳ |
| B | | | O | Oo | Oo | Oo | OXoΔ | OXoΔ | OXo | Discontinued for winter | | | | OXo | OΔ | OoΔ⊳ | OXoΔ |
| C | | | | | | O | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | | | | OXoΔ⊳ |
| R | | | | | | | OXoΔ⊳ | OXoΔ⊳ | Oo | OoΔ⊳ | OoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | OXoΔ⊳ | OXoΔ | OXoΔ |
| EE | | | O | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo | Oo |
| S | OX | | | | | | OXoΔ | OXΔ | OXoΔ | OXΔ | OXoΔ | OXΔ | OXΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | OXoΔ |
| T | | | | | | | OXΔ | OX | OXoΔ | OXo | OXoΔ⊳ | OXoΔ | OXo | OXoΔ | OXoΔ | OXoΔ | OXoΔ |
| U | | | | | | | O | OXΔ | OXo | OXo | OXo | OXoΔ | OXo | OXo | OXo | OXoΔ | OXoΔ |
| V | | | | | | | OXΔ | OXΔ | OXo | OXoΔ | OXo | OX | OXo | OXo | OXo | OXoΔ⊳ | OXoΔ |
| W | | | | | | | | | | OXoΔ | OXo | OXo | OXoΔ | OXo | OXoΔ | OXoΔ | OXoΔ |
| J | | | | | | | | | OXoΔ | | OXoΔ | OXoΔ | | OXoΔ | OXoΔ | OXoΔ | OXoΔ |
| L | | | | OX | | OXo | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | | OXoΔ | | OXoΔ | OoΔ | OoΔ |
| M | | OXoΔ | | OXo | OXo | OXo | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXo | OXoΔ | OXoΔ⊳ | OXoΔ | | OXoΔ | Oo | OoΔ |
| N | | | | OX | OXo | OXo | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | | OXoΔ | OoΔ | OoΔ⊳ |
| O | | OXΔ | | OXo | OXo | OXo | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXo | OXo | OXoΔ⊳ | OXoΔ⊳ | | OXoΔ | OoΔ⊳ | OoΔ⊳ |
| P | | OXΔ | | OXo | OXo | OXo | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ⊳ | OXoΔ | OXoΔ | | OXoΔ⊳ | OoΔ⊳ | OoΔ |
| D | OXΔ | OXo | OXo | OXo | OXo | | OXoΔ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | OXoΔ | OXΔ | OXoΔ | OoΔ | OoΔ⊳ | OoΔ |
| FF | | Oo | Oo | | | | Oo | Oo | Oo | Oo | Oo | Oo | | Oo | Oo | | Oo |
| GG | O | Oo | Oo | | | | Oo | Oo | Oo | Oo | Oo | Oo | | Oo | Oo | | Oo |
| HH | O | Oo | Oo | | | | Oo | Oo | Oo | Oo | Oo | Oo | | Oo | Oo | | Oo |
| II | O | Oo | Oo | | | | Oo | Oo | Oo | Oo | Oo | Oo | | Oo | Oo | | Oo |
| E | OX | OX | OXo | OXo | OXo | OXo | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | OXoΔ⊳ | OoΔ | OoΔ |
| F | OX | OXo | OXo | OXo | OXo | OXo | OXoΔ | OXoΔ⊳ | OXoΔ | OXoΔ | OXoΔ | OXoΔ | | OXoΔ | OoΔ⊳ | OoΔ | OoΔ |
| K | O | OXo | OXo | OXo | OXo | OXo | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OXoΔ⊳ | OoΔ⊳ | OXoΔ | OoΔ | OoΔ | OoΔ |
| AA | O | OXo | OXo | OXo | OXo | Oo | OXo | OXoΔ | OXo | OXo | OXo | OXoΔ | | OXΔ | | | OoΔ |
| BB | O | Oo | OXo | OXo | OXo | OXo | OXoΔ | OXo | OXo | OXoΔ | OXo | OXoΔ | | OXoΔ | | | OoΔ |
| CC | OX | OX | OXo | OXo | OXo | OXo | OXoΔ | OXo | | | Oo | | | OXo | | | OoΔ |
| DD | O | OXo | OXo | OXo | OXo | OXo | OXoΔ | OXΔ | OXo | OXo | OXo | OXoΔ | | OXoΔ | | | OoΔ |

KEY:
O Site visit (operation, odor, and temperature observations)
X Vector sample
o Fly tape and toilet seat swab
Δ Analytical (includes physical, chemical, total, and fecal coliform)
⊳ Pathogen screen

available to project staff for three to five months after the sampling occurred and as such did not influence choices made until the last few months when an effort was made to follow up earlier findings. The types and number of systems from which data were obtained during the February 1979 through June 1980 duration of the field data collection phase are summarized below.

| Waterless Toilets | |
|---|---|
| Large sloped fiberglass toilet | 8 |
| Large sloped plastic toilet | 3 |
| Box-like humus toilet with topping bar | 4 |
| Box-like humus toilet with rotor | 4 |
| Vault privy | 5 |
| Pit privy | 4 |
| Drum toilet | 4 |
| Total | 32 |

| Grey Water Systems | |
|---|---|
| Septic tank | 1 |
| Proprietary settling tank | 2 |
| Single media filter | 1 |
| Dual media filter | 2 |
| No treatment | 3 |
| Total | 9 |

The types and number of systems studied are presented in Tables 5.10 and 5.20. These tables also show the number of actual site visits to each unit installation by month and the extent of data collection activities during the site visit.

## 5.2 FIELD SAMPLING AND MONITORING TECHNIQUES

The objective of the field sampling and monitoring work was to obtain as much information as possible on the operation and performance of the selected systems and on the biological, physical, and chemical aspects of the stored excreta solids, liquid, and grey water collection and treatment over a 12-month period (i.e., systems' performance over the four seasons). No attempt was made to control the amount of usage of the units by the occupants or to influence the users' decisions in operating and maintenance practices.

All persons involved in the routine sampling and monitoring were individually instructed on the first visit to the sites of their assigned systems by the field biologist and/or the project director to standardize as much as possible the data collection activities. To facilitate accurate and uniform recording of observations and collection of data at each site visit, they were provided with written instructions and a field survey form designed by project staff. Each sample was identified by a code number which communicated the type of system, state of materials tested, and county of location, while protecting the privacy of the participating residents.

### Data and Sample Collection from Waterless Toilets

**Observation of Site and Unit Conditions**—Upon arriving at the site, the field investigators noted wind direction and speed. Moving upwind toward the unit, they recorded any odor associated with the toilets at distances of 100 feet and 50 feet from the toilet vent stack and at the residence. Distinction was made between hydrogen sulfide and ammonia odors. The investigators then interviewed the occupants concerning general and specific details of the unit operation, problems, and extent of use. Entering the bathroom or privy house, they noted presence of odor at the toilet port and looked for signs of excessive numbers of flies or other insects in the room. A swab of the toilet chute and seat was taken as described under "Observations and Sampling of Arthropods."

At the vault of the unit, they noted signs of spillage, leakage, vector invasion, and odors. At this point, the investigators donned disposable surgical examination gloves. If it was necessary for them to lean into the vault, it was recommended that they cover the hair with a plastic bag and wear safety glasses or goggles and paper face masks. The access port was opened and the inside of the vault examined by flashlight for arthropods. Specimens were collected as described in the next section. Odors within the vault were noted. Distribution of accumulated solids and liquid was drawn in on the diagram of the unit provided with the field survey form; leaks, structural problems, etc. were reported.

TABLE 5.20 GREY WATER SYSTEMS

| SYSTEM | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | ○Δ | ○Δ | | | ○Δ | | | | | |
| 2 | | | | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | |
| 3 | | | | | | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ |
| 4 | ○ | | | | | | ○ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ➤ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ |
| 5 | ○ | | | | | | ○ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ➤ | ○Δ | | ○Δ | | ○XΔ |
| 6 | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ | ○XΔ | ○XΔ | ○XΔ➤ | ○ | |
| 7 | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ | ○XΔ | ○XΔ | ○XΔ➤ | ○ | |
| 8 | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ➤ | ○Δ➤ | ○XΔ | ○XΔ➤ | ○XΔ➤ | ○XΔ | ○XΔ➤ | ○XΔ➤ |
| 9 | | | | | | | ○Δ | ○Δ | ○Δ | ○Δ | ○Δ | ○XΔ | ○XΔ | ○XΔ | ○XΔ | ○XΔ | ○XΔ |

KEY:
○ Site visit (operation, odor, and temperature observations)
X Vector sample
Φ Fly tape and toilet seat swab
Δ Analytical (includes physical, chemical, total, and fecal coliform)
➤ Pathogen screen

Temperatures were taken at the center and at the edge of the pile of solids, each at one-half the depth of the pile. In units with separation of fresh and decomposed solids, temperatures were taken in each pile. For units with heating coils, an additional reading was made near the coil. For the large vault units, a dial-top bimetal thermometer with a two-foot steel shank was wrapped in a plastic bag and inserted. For the smaller units, a glass and mercury thermometer was used. Temperatures in pit privies were taken using a thermistor thermometer fitted with a surface/immersion probe on an 18-foot flexible lead. When thermometers or other equipment came in direct contact with solids, they were sanitized with a 2 percent solution of Staphene disinfectant and rinsed with water.

When field determination of the pH of the solids was required, nonbleeding ColorpHast indicator strips with pH ranges of 4.0–7.0 and 6.5–10.0 were used. The strip was moistened with distilled water, touched to the solids for 30 seconds, and immediately compared with the color charts provided. The status of decomposition of the solids was described based on particle size and uniformity, color, and distribution of moisture.

Finally, before closing the vault, solids samples were taken for submission to the Berkeley laboratories of the DOHS using procedures detailed in the next two sections, and the exposed sticky fly tapes and cockroach traps were replaced with new ones.

**Observations and Sampling of Arthropods**—During each site visit, representative specimens of insects, spiders, mites, and other arthropods found associated with the units were collected. Flying insects were taken with an insect net, killed in a cyanide bottle, and placed between tissue papers in labeled boxes containing chlorocresol, a mold inhibitor and relaxant. Arthropods crawling on the solids and vault walls were picked up with forceps or a camel's hair artist's brush moistened with alcohol. These specimens were preserved and shipped in 80 percent ethanol. The presence of mites or other arthropods on or in the immediate area of the toilet seat or kitchen port, if installed, was determined by swabbing these ports with a 15 x 15 cm white cotton flannel mitten which picked up the tiny specimens in the nap of the cloth. All components of the toilet seat, the cover, and the chute lip upon which the seat rests were swabbed; the mitten was then sealed in a plastic bag for submission to the laboratory.

The occurrence of flying insects in the vault during the previous month was determined by hanging a Pic or Aeroxon sticky fly tape in the vault at a location out of the way of fouling. Exposed tapes were extended and carefully placed on a sheet of clear plastic wrap and covered by folding the wrap over the tape. To detect the presence of cockroaches in the vault, a Zoecon cockroach sticky trap was placed in a corner of the vault. Exposed traps were placed in plastic bags for submission.

Samples of solids for arthropod extraction were taken from both the fresher pile in the vault and from the decomposed pile in the removal chamber if present. Each of these samples was a composite of four subsamples taken at the edge, center, and at intermediate levels in the pile; the total sample amounted to approximately one liter. The solids were removed from the vaults using a liter-sized cylindrical scoop attached at right angles to a one-foot handle. The scoop was lined with 18" x 8" x 4" plastic bag which was turned down over the outside of the scoop so that the exterior of the scoop and the bag were not contaminated. The bag containing the sample was then removed from the scoop and placed in a ½-gallon ice cream carton for transport. The bag was left open and a few small holes were punched in the top of the ice cream carton to prevent accumulation of gases toxic to insect larvae.

**Sample Collection for Basic Laboratory and Pathogen Analyses**—Solids samples for the various microbiological, physical, and chemical analyses were taken from the vaults with the plastic bag-lined scoop as described above. Early in the study, a one-liter sample was shipped in the same manner as the solids for arthropod extraction and separated for these analyses at the Berkeley laboratory facility. Later, these samples were taken separately by the field investigator. One-pint waxed cardboard containers were used to package solids for total and fecal coliform analyses, for parasite and virus screening and for bacterial screens which would identify *Salmonella* forms. An eight-ounce moisture-proof plastic container with gasketed top was used in submitting the sample for physical and chemical analyses.

The areas in the solids mass of fresh material, intermediate-aged material, and "finished" (decomposed) material from which samples were selected varied with the specific analysis needs of the unit being sampled. Instructions describing the desired sampling were furnished to the field investigators monthly, prior to the site visit.

Leachate accumulation in the vaults was sampled by suction using a plastic turkey baster. Samples for microbiological tests were submitted in sterile four-ounce plastic bottles containing sodium thiosulfate as a dechlorinating agent. Samples for physical and chemical analyses were put into a clean ½-gallon plastic bottle.

### Data and Sample Collection from Grey Water Systems

At sites of grey water systems, investigators were to examine the immediate area for signs of leakage and overflow due to surge loading of the treatment unit. Presence or absence of odors and insects, especially mosquitoes, was noted. Upon opening the access port, they were to observe and report degrees of scum layer and settled solids buildup. Disposal areas were not routinely subjected to observation. Water samples were removed from the treatment unit using a plastic turkey baster or the solids scoop lined with a plastic bag. Those for microbiological analyses were poured into a sterile four-ounce plastic bottle containing sodium thiosulfate as a dechlorinating agent. Those to be tested for physical and chemical parameters and parasites were poured into a clean ½-gallon disposable plastic bottle. In the systems where grey water was treated, grab samples of both the influent and the effluent were taken.

### Sample Storage and Transport

All field-collected samples were shipped to the DOHS laboratories in Berkeley in 32" x 20" x 14" insulated boxes. The samples rested on four blue ice packs, held in place with covers of four-inch thick flexible foam cut to fit the boxes. Most shipments were by Greyhound Bus "first bus out" service; these routinely arrived within the 30-hour period specified by the laboratories for uniform microbiological analyses. Upon arrival at the Berkeley facility, any samples to be composited for the basic laboratory and pathogen analyses were well mixed under a hood, and aliquots were transferred to separate containers for the bacterial, viral, and parasite screens as required. Temperatures of the sample were not taken upon arrival at the laboratory; but with few exceptions, the blue ice packs were still partially frozen and the samples were thoroughly cooled.

Each month, the shipping containers were returned to the field investigators along with the necessary instructions, field survey forms, sampling devices and site-coded, dated containers.

### Sample Variation

When analyzing data obtained from samples and field survey forms submitted by project field personnel, it should be kept in mind that this investigation was not a controlled laboratory study and difficulties were encountered at times in carrying out the standardized procedures presented above. Gaps in the monthly sample collections occurred when the occupants were not home or weather conditions prevented access to the sites. Solids samples from the vaults were prone to variation, especially in the fresh material area, because the contents were so diversified depending on the amount of use of the unit, what the users had added, and how the pile was covered with kitchen wastes when the sampling was conducted, making it difficult to decide where to take a "fresh" sample. Occasionally a shipment was delayed en route and arrived at room temperature.

Situations uniformly encountered by field investigators were contamination of end product samples with fresh material or leachate, and mixture of end product samples with peat moss or soil bedding material. Contamination was least frequent in the small box-like toilets with rotors, vault privies, and drum privies because of these units' complete separation of end product from fresh additions during its final storage or treatment period. The other unit types were more prone to contamination, especially from leachate. Instances of bedding material being sampled entirely or partly in place of end product are due to physical resemblances between the materials.

Regarding unit operation, field investigators attempted to obtain information on number of users, additives used, extent of maintenance, and any observations that would affect the performance of the unit. As with sampling procedure, reporting procedure varied slightly from county to county; field investigators' comments often varied in extent and content. Further, these comments often reflected the relative willingness or shyness of the occupants to report such information.

The impact of sample variation on the results is difficult to determine precisely. Certainly, unusual deviations in individual sample analysis results could be attributable to problems in collection or shipment. However, when several data points were obtained on a specific unit, trends often became apparent which indicated the results had validity and were reasonably comparable with other units of a type with other unit types. However, such variations within a relatively small number of samples make interpolation of the results to biological toilets in general qualitative at best.

## 5.3 VECTOR EXTRACTION AND IDENTIFICATION OF ARTHROPODS

Insects, mites, etc., were extracted from the vault solids samples using a modified Tullgren funnel. The operation of this device relies on the negative taxes of arthropods in response to gradual heating and drying of the substrate. Modified procedures were adopted to prevent escape of potentially contaminated vectors from the extraction system. The stems of the funnels extended well into the quart jars containing alcohol into which the arthropods dropped when they fell through the screens supporting the solids. In addition, a sleeve of plastic wrap was placed around the funnel and jar, and the jar was placed in a water bath. Flies emerging from pupae in the solids were caught in emergence traps placed over the tops of the 15" diameter funnels. These traps consisted of shallow cones constructed of aluminum window screen covered with fine nylon netting (30 denier). An opening at the top of the cone allowed the flies to enter a cardboard cylinder whose upper end was covered with netting, after being induced to move up and out into the cylinder by the light of the 100 watt incandescent bulb which also heated and dried the solids at temperatures of 40°–50°C. The solids near the top dried in 2–3 days. This mass was then examined for fly puparia (the covering of a nonmotile stage), which were retained for identification.

The flannel cloths used in swabbing the toilet seat areas were examined under a dissecting microscope for mites and other arthropods. These were removed with forceps into 80 percent ethanol. For identification, mites were mounted on microscope slides in Berlese medium. The cloths were disinfected with Staphene, rinsed, dried, and reused.

Flies and other flying insects collected on the sticky fly tapes were identified by viewing them through the clear plastic wrap covering the tapes, using a low power dissecting microscope. When necessary for closer examination, the insects were removed from the sticky tapes by immersion of a small cut out section in xylene, which dissolved the sticky substance. These insects were rinsed and stored in 80 percent ethanol.

## 5.4 LABORATORY ANALYTICAL PROCEDURES

### Coliform Assays

Coliform and fecal coliform bacteria were enumerated for solid waterless toilet solids by means of an MPN procedure described in ***Recommended Procedures for the Examination of Sea Water and Shellfish,*** American Public Health Association, 4th Edition, 1970, modification from the method suggested for shellfish included an initial dilution of 1 gm sample plus 9 ml diluent (phosphate dilution water) and a dilution range extending to $10^{-8}$. These modifications permitted complete homogenization of a representative sample, a sample consistency amenable to pipetting, and a dilution range suitable for MPN enumeration of both fresh and stored material which was at least partially of fecal origin. Liquid samples were analyzed as per the 14th edition of ***Standard Methods.***

### Bacteria Screen

Approximately eight grams of feces was placed into duplicate jars of selenite-cystine and tetrathionate-brilliant green broth. After 18–24 hours incubation at 35°C, each bottle of enrichment broth was streaked onto duplicate plates of Bismuth Sulfite (BS), Brilliant Green (BG) and ***Salmonella-Shigella*** (SS) agar. Colonies resembling those of ***Salmonella*** or ***Shigella*** were picked from the plates onto Triple Sugar Iron (TSI) agar. Slants showing an alkaline slant and an acid britt were inoculated into ONPG medium and urea sugar. Cultures which gave a positive reaction in either medium were considered not to belong to the genus ***Salmonella*** or the genus ***Shigella.*** Colonies producing negative results in both media were subjected to additional biochemical tests. Any culture giving a biochemical pattern similar to that of *Salmonella* sp. was confirmed by serological testing with *Salmonella* polyvalent antiserum. A few isolates not resembling *Salmonella* or *Shigella* were biochemically tested for identification purposes.

**Parasite Screen**

The Microbial Diseases Laboratory devised the following scheme for screening for parasites in the solids samples:[47, 48]

**Sample Size**—One-pint ice cream cartons are filled with material from representative areas of the compost. The contents of one ice cream carton represent one specimen.

**Method—Screening Procedure:**

1. Place approximately ½ of the compost (depending on the amount available) from one ice cream carton into a one liter screw cap flask (transfer can be facilitated by using a funnel made from a sheet of 8½ x 11 inch paper).
2. Add enough tap water to fill approximately 1/2 to 3/4 of the flask (depending on the amount and composition of the compost).
3. Shake for one minute.
4. Using two layers of wet gauze, filter into a 500 ml screw cap flask.
5. Fill two 40 ml conical centrifuge tubes with the filtrate to within 3/4 inch of the top.
6. Centrifuge for 2 minutes at 2,000 rpm (650 g).
7. Discard the supernatant fluid.
8. Flame the top of the tubes.
9. Add enough $ZnSO_4$ (specific gravity 1.180) to fill ½ each tube.
10. Mix with applicator sticks.
11. Fill the tubes to within 3/4 inch of the top with $ZnSO_4$.
12. Centrifuge for 1 minute at 2,000 rpm (650 g).
13. Carefully remove 1.0 ml of the surface film from each tube using a pipette and place in a 15 ml conical centrifuge tube.
14. Add tap water to the 12 ml mark and mix with applicator sticks.
15. Centrifuge at 1,700 rpm (500 g) for one minute.
16. Remove the supernatant fluid with a pipette so as to leave approximately 0.2 ml of sediment.
17. Mix thoroughly with a Pasteur pipette and take all the sediment into the pipette before making a mount.

18. Prepare the following mounts:

    a. Iodine Mount

        (1) Add a drop of sediment to 1 drop of Lugol's iodine (diluted 1:5 with distilled water).

        (2) Mix and cover with a 22 mm square coverslip.

        (3) Seal with Vaspar and examine for cysts, eggs, and larvae.

    b. Saline Mount (Hanging Drop)

        (1) Using a wax pencil, draw a circle on a 22 mm coverslip which will be slightly smaller than the well it will be inverted on.

        (2) Place four small drops of Vaspar around the area of the well. This will tend to raise the coverslip off the slide for better access to oxygen and will help to keep the coverslip from sliding around.

        (3) To a drop of saline placed on the ringed area of the coverslip, add a drop of sediment.

        (4) Mix with an applicator stick.

        (5) Invert the coverslip and place on the four drops of Vaspar.

        (6) Examine for eggs and larvae.

        (7) If no eggs or larvae, resembling those found in humans, are found in either the iodine or saline mounts, report as "No known human parasites found."

        (8) If eggs resembling those found with human parasites are seen, place the slide with the saline hanging drop in a moist chamber (large plastic Petri dishes with wet cotton balls). Eggs are examined daily for one month to ascertain viability. (Note: $ZnSO_4$ may have an adverse effect on organisms, so proceed to the next procedure.)

        (9) If eggs, suspected to be those of human parasites and/or larvae, are found which must be ruled out from the free-living types, also proceed to the next procedure.

**Further Confirmation and Viability Testing**

1. Using the mixture obtained in step 4 of the screening procedure, fill two 15 ml conical centrifuge tubes to the 10 ml mark.

2. Centrifuge at 2,000 rpm (650 g) for 2 minutes.

3. Discard the supernatant fluid.

4. Flame the mouths of the tubes.

5. To one tube, add a 1:30 dilution of HCl to the 10 ml mark.

6. To the other tube, add tap water to the 10 ml mark.

7. Mix both tubes with applicator sticks.

8. Centrifuge both tubes at 1,700 rpm (500 g) for 1 minute.

9. Discard the supernatant fluid.

10. Flame the mouths of the tubes.

11. Prepare hanging drop mounts from each tube. If eggs resembling those found with human parasites are present in the untreated sample, examine for viability for one month. Examine for motile larvae. Free-living nematodes are killed almost immediately by dilute HCl; infective larvae of parasitic species live for about 24 hours. Larvae can be specifically identified by morphologic features. A moist chamber may be used to hold the slides. If necessary, a filter strip egg hatching technique may be used. Subsequently on checking with parasitologists at University of California and the Center for Disease Control Laboratory, we learned that this is not an acceptable method for distinguishing between free-living and parasitic larvae.

### Filter Strip Egg Hatching Technique

1. Cut filter paper so as to be one inch wide and seven inches long.

2. Smear about 1/2 gram of feces (a quantity about the size of a small pea) over approximately 1/2 to 2/3 the length of the filter paper.

3. Place the strips in at least six large metal stoppered tubes containing approximately three ml of tap water in the bottom. The lower edge of the filter paper should be in the water but the feces does not have to be submerged.

4. Incubate at room temperature for three to seven days. Filariform larvae will be found at the bottom of the tube.

5. Examine at three days for *Strongyloides* larvae and after five to seven days for hookworm.

6. Water from several tubes may be combined and centrifuged.

7. Dilute HCl may then be used to rule out free-living nematodes.

### Virus Assays

Fresh and finished solid specimens were weighed and diluted to 1,000 ml with sterile distilled water. The mixture was mixed thoroughly, allowed to extract for an hour, and clarified by pouring through a layer of cheese cloth to remove most of the debris. Leachate and grey water samples were measured and diluted to 500 ml with sterile distilled water. The liquid mixture resulting from leachate and grey water samples and the liquid extract resulting from solid sample preparation were each treated as below.

Powdered beef extract was dissolved to 10 percent concentration in the sample solution. 0.12 N HCl was added until a flocculate appears and a final pH of 3.5 is reached. The mixture is allowed to settle at 4°C for 12–18 hours. The liquid fraction is carefully aspirated off, leaving flocculate which is then dissolved in 0.15 M $Na_2HPO_4$ to a volume of 20–30 ml. Before inoculation onto cell lines, the sample is extracted with chloroform to remove bacteria and fungi. In most instances, African green monkey kidney and human rhabdomyosarcoma were used as host systems.

**Physical and Chemical Analyses**

The following references identify methodology used for analytical work on both solid and liquid samples.

| PARAMETER | SM/EPA* | SECTION | PAGE |
|---|---|---|---|
| 1. pH | SM | 424 | 460 |
| 2. Percent Moisture | SM | 208A | 91 |
| 3. Percent Total Solids | SM | 208A | 91 |
| 4. Percent Volatile Solids | SM | 208F | 95 |
| 5. Percent Ash | SM | 208F | 95 |
| 6. Total Dissolved Solids | SM | 208B | 92 |
| 7. Specific Conductance | SM | 205 | F1 |
| 8. Total Organic Nitrogen | EPA | 351.4–2 | –– |
|  | and |  |  |
|  | SM | 421 | 437 |
| 9. Biochemical Oxygen Demand | SM | 507 | 543 |
| 10. Chemical Oxygen Demand | SM | 508 | 550 |
|  | and |  |  |
|  | EPA | 410.1 | –– |
| 11. Suspended Solids | SM | 208D | 94 |
|  | and |  |  |
|  | EPA | 160.2 | –– |
| 12. Nitrate | SM | 419D | 427 |
|  | and |  |  |
|  | EPA | 352.1 | –– |
| 13. Nitrite | EPA | 353.1 | –– |

* SM = APHA, AWWA, WOCF. *Standard Methods for Examination of Water and Wastewater.* 14th Edition, 1976.
EPA = USEPA. *EPA Methods for Chemical Analysis of Water and Wastes.* EPA–600/4–79–020, March 1979.

# SECTION 6
# GREY WATER UNIT DESCRIPTION, FIELD FINDINGS, CHARACTERISTICS, AND DISCUSSION OF RESULTS

Three levels of grey water treatment including settling, media filtration, and no treatment were evaluated under field conditions over an 11-month period. A summary of each site shown on Table 6.10 describes the level of treatment, the contributing source waters, and the reuse or disposal method. The following discusses analytical findings about each grey water site.

## 6.1 COLLECTION, NO TREATMENT

The most basic system is simply a direct line between source and reuse site. However, the most common reuse is some form of irrigation which logically does not occur in an unplanned or sporadic manner. Consequently, the grey waters need to be collected so that irrigation practices can be efficient. The three collection-only systems that were evaluated basically "contained" a limited quantity of grey water without purposeful settling or media filtration before irrigation reuse occurred. The mechanics of each system were such that no predictable residence time took place in the collection vessel.

The determinants for this type of system are the absence and prevention of odors and vectors and the exclusion of source waters that contain contaminants such as grease and organic contaminants from the kitchen sink. The success of grey water reuse depends heavily on the environmental setting as well as the practicality of the disposal technique. The appropriateness of a particular grey water reuse application, of course, ultimately depends on many site-specific factors including population density and water quality.

About 30 grab samples were collected and analyzed from 3 simple collection-reuse systems. As noted on Table 6.10, combinations of bathroom sink, shower and washing machine source waters were reused. The two desert sites, Units 4 and 5, both used the grey water for surface irrigation of ornamental landscape adjacent to each homesite. The latter site also used this water for a pigpen. The coastal site, Unit 9, collected bathroom sink and shower water which was distributed by means of a dosing siphon to a subsurface leach field that was planted with berries.

## TABLE 6.10
## GREY WATER SUMMARY

| UNIT | NUMBER OF DATA POINTS | | SOURCE OF GREY WATER | | | | | | | TYPE OF REUSE/DISPOSAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Influent | Effluent | Kitchen Sink | Dish-washer | Bath-room Sink | Tub/ Shower | Washing Machine | Toilet Leachate | Other | Surface | Sub-Surface | Orna-mental Landscape | Tree | Vegetables | Animal | No Planned Reuse |
| **Collection Only** | | | | | | | | | | | | | | | | |
| 4 | 11 | N/A | | | X | | X | | | X | | X | | | | |
| 5 | 9 | N/A | | | | | X | | | X | | X | | | X | |
| 9 | 10 | N/A | | | X | X | | | | | X | | | | | |
| **Settling Only** | | | | | | | | | | | | | | | | |
| 7 | 9 | 0* | X | | X | X | | | | | X | | | | | X |
| 2 | 8 | 8 | X | X | X | X | X | X** | | | X | | | X | | |
| 3 | 6 | 6 | X | X | X | X | X | X** | | | X | | | | | X |
| **Media Filtration** | | | | | | | | | | | | | | | | |
| 1 | 0* | 3 | X | X | X | X | X | X | | X | X | X | | | | |
| 6 | 11 | 11 | X | X | X | X | | | | | X | X | | | | |
| 8 | 11 | 11 | X | | X | | | | dairy & laundry sink | X | | | | X | | |

* Samples inaccessible

** Not used during study.

## TABLE 6.11
## UNITS WITH NO TREATMENT: BACTERIOLOGICAL FINDINGS

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 ML | | FECAL COLIFORM MPN ORGANISMS/100 ML | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| 4 | 11 | $10^3-10^7$ | $8.4 \times 10^4$ | $<10-10^3$ | $5.2 \times 10$ |
| 5 | 8 | $10^2-10^5$ | $3.4 \times 10^3$ | $10-10^4$ | $1.6 \times 10^3$ |
| 9 | 10 | $10^8-10^9$ | $6.3 \times 10^8$ | $<10-10^6$ | $4.9 \times 10^3$ |

Table 6.11 shows bacteriological findings for three no-treatment systems. Although a wide variation of 7 logs exists in coliform findings among the 3 systems, individual sites demonstrated much consistency by showing a 2- to 4-log variation over an 11-month sampling year. No such consistency was shown in the more important fecal coliform data where 3- to 6-log variations existed. Two samples from Unit 4 were further screened for virus with no isolations and for bacteria with *Enterobacter* and *Citrobacter* forms identified in both samples.

Although data are limited, the results show that the two systems in a desert environment primarily diverting washing machine rinse water contain significantly lower total and fecal coliform than the single coastal system which receives only bathroom basin and shower waters. This latter unit consistently contained two to three times the quantity of coliform organisms found in waters from the clothes-washing activity. These findings are similar to other findings in which it was concluded that both clothes-washing and bathing activities are known to generate a wide range of indicator organisms.[80] It is difficult to assess the effect of environmental setting with these data. Also, the fecal coliform densities from all three sites were generally lower than reported by other investigators.[10, 11]

## TABLE 6.12
## UNITS WITH NO TREATMENT: CHEMICAL FINDING

| SYSTEM | NUMBER OF DATA POINTS | BOD, mg/l |  | COD, mg/l |  | TOTAL N, mg/l |  | TDS, mg/l |  | SS, mg/l |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 4 | 10 | 40–550 | 150 | 60–770 | 268 | 2–20 | 8 | 420–980 | 558 | 20–400 | 144 |
| 5 | 8 | 40–190 | 76 | 80–1,300 | 305 | 5–20 | 11 | 490–780 | 646 | 60–1,500 | 191 |
| 9 | 10 | 140–620 | 250 | 160–1,610 | 374 | 1–50 | 22 | 150–1,700 | 265 | 30–670 | 103 |

The results of analytical work reported in Table 6.12 show untreated grey water comparable to primary treated sewage with the exception of total nitrogen and, in some instances, to raw sewage. Wide variations in sample results are probably due to the nature of grab sampling which was performed at each collection vessel and/or normal household variations. These results support the position that grey water must be considered to be sewage regardless of whether toilet wastes are separately treated.[78]

Since routine site observations of the reuse were not recorded, it is not known whether any benefit or damage occurred to the irrigated landscape or to the immediate environment due to the water quality. It is also unknown whether or not each irrigation site was supplemented by other water sources. With limited data, conclusions about the appropriateness of each reuse cannot be determined. Ultimate acceptability of similar systems must be judged against site-specific factors and community health standards.

## 6.2 COLLECTION, SETTLING

The second set of treatment options involves purposeful containment for the removal of particulates either by sedimentation and/or by surface skimming. The three systems evaluated were a septic tank and two types of proprietary systems specifically marketed for their ability to remove particulates from grey water. Determinants for this process are those previously listed for no treatment systems as well as the ability to remove particulates by settling.

The three systems monitored all make use of techniques common to primary sewage treatment. Collection is followed by a quiescent state which allows for particulates to settle and the lighter fraction to float to the surface. Disposal of the clarified fraction is by means of a subsurface leach field. Influent samples were collected in the initial collection chamber and effluent samples in the final collection chamber. Each system differed structurally.

Unit 7 used the traditional septic tank-leach field. A retrofit waterless toilet (see Unit S) handled the black wastes. Household sink and shower waters were contained and disposed of on site with no intentional reuse occurring. An observation/sampling port was proposed for installation at the end of the leach field but was not installed. Inconsistencies in data quality may be attributable to several sets of tenants occupying this rental home during the course of the study. Both Units 2 and 3 are proprietary units marketed specifically for grey water disposal. The former is a 200-gallon sludge separator unit; the latter consists of three 60-gallon settling tanks connected in series. Black wastes at both sites are contained within waterless toilets G and H. No secondary reuse of grey water was planned for these three sites. Corn was planted above the leach field for Unit 2 as an afterthought.

Table 6.21 reports microbiological findings for Units 2, 3, and 7. These findings show virtually no reduction of coliform content during the settling process. They also show that a major portion of the total coliform organisms detected are of fecal origin. One influent and two effluent samples from Unit 2 were subjected to additional bacterial investigation. Seven opportunistic bacteria forms (see Appendix A) were identified including ***Klebsiella pneumoniae*** in all three samples. Two effluent samples were screened for parasites, one was also analyzed for virus. No known human parasites were found, although ciliates were observed in both effluent samples. Similar pathogen forms are assumed to survive under similar conditions. No virus were isolated. These findings suggest that settling grey water does not reduce the existing potential of raw grey water to contain biologically hazardous organisms.

## TABLE 6.21
## UNITS WITH SETTLING: BACTERIOLOGICAL FINDINGS

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 ML | | FECAL COLIFORM MPN ORGANISMS/100 ML | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| 2 Influent | 6, 8 | $10^7$–$10^9$ | $2.8 \times 10^8$ | $10^5$–$10^8$ | $5.2 \times 10^6$ |
| 2 Effluent | 5, 8 | $10^7$–$10^9$ | $3.9 \times 10^8$ | $10^5$–$10^8$ | $5.1 \times 10^6$ |
| 3 Influent | 6, 5 | $10^7$–$10^9$ | $3.1 \times 10^8$ | $10^5$–$10^7$ | $5.5 \times 10^6$ |
| 3 Effluent | 6, 6 | $10^7$–$10^9$ | $4.1 \times 10^8$ | $10^6$–$10^7$ | $1.1 \times 10^7$ |
| 7 Influent | 9, 9 | $10^4$–$10^8$ | $6.2 \times 10^6$ | 10–$10^7$ | $3.2 \times 10^5$ |

A summary of the results of analytical work for Units, 2, 3, and 7 is shown on Table 6.22. The effluent quality of Units 2 and 3 is similar to raw domestic sewage. While Unit 2 consistently demonstrated a reduction in water quality for all measured constituents, Unit 3 generally improved the quality of influent grey water. It appears that the three-chambered Unit 3 provides a better environment to settle out some of the particulate matter. The negative performance of Unit 2 was not readily explained since a similar unit performed about as well as Unit 3 in an Oregon field study.[87] The performance of Unit 7 cannot be assessed since it was not possible to sample system effluent; however, the quality of influent to this Unit is similar to the influent from Units 2 and 3. The reported inability of the soil absorption system of Unit 7 to adequately percolate the grey water treatment unit effluent during this study is probably related to existing problems with proximity to high ground water table and with system condition.

## TABLE 6.22
## UNITS WITH SETTLING: CHEMICAL FINDINGS

| SYSTEM | NUMBER OF DATA POINTS | BOD, mg/l | | COD, mg/l | | TOTAL N, mg/l | | TDS, mg/l | | SS, mg/l | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 2 Influent | 8 | 90–330 | 150 | 50–430 | 200 | 10–30 | 14 | 140–350 | 220 | 20–270 | 60 |
| 2 Effluent | 8 | 190–560 | 300 | 50–1,200 | 510 | 10–30 | 19 | 190–320 | 240 | 120–520 | 250 |
| 3 Influent | 7 | 180–4,900 | 506 | 350–7,400 | 932 | 5–60 | 12 | 290–910 | 462 | 60–1,900 | 209 |
| 3 Effluent | 7 | 200–830 | 307 | 280–1,300 | 419 | 10–20 | 7 | 340–810 | 497 | 30–440 | 130 |
| 7 Influent | 8 | 100–720 | 226 | 190–1,600 | 380 | 20–90 | 33 | 300–400 | 345 | 60–780 | 119 |

### 6.3 MEDIA FILTRATION

The third option studied was grey water filtration by one or more media. Performance of this type of system is measured by its ability to significantly reduce physical, chemical, and microbiological contaminants. The following three systems all used one or more media in homeowner-built filtration units.

Unit 1 used pea gravel filter medium and shallow subsurface leach lines to irrigate nearby fruit and pine trees. In addition to receiving all household grey waters, the unit was plumbed to receive the liquid buildup from the waterless toilet Unit I located within the house. Only three effluent samples were available from this unit because of difficulties with access to the site. There were no provisions for influent sampling. Winter site conditions appeared to affect the ability of the shallow leach field to adequately dispose of the grey water since the filter vessel was observed overflowing during periods of snow cover.

Unit 6 consisted of a three-chamber settling system followed by a dual media filter that contained crushed dolomite and sand. The grey water effluent was used to irrigate an ornamental landscape garden area by means of a 25-foot shallow, subsurface leach line. The succulents being irrigated decreased in size with their distance from the grey water filter box; irrigation waters probably did not fully charge the leach line. Odors during warm weather prompted the owner to consider burial of the filter box; however, representatives of the on-site management district felt this would hinder surveillance.

Grey water Unit 8 consisted of a three-chamber settling tank configuration and a dual media filtration chamber containing river gravel and sand. A 25-gallon dosing siphon in the final settling chamber delivered settled grey water to the filter chamber onto a splash plate. The filter, which was designed to operate as a slow sand filter, was sized to handle up to 75 gallons per day. The unit was monitored monthly over an 11-month period including a 6-month period when usage was minimal. Odors during warm weather prompted improvement of the seals on the filter access cover. Treated grey water was used to surface irrigate a food garden area.

## TABLE 6.31
## UNITS WITH FILTRATION: BACTERIOLOGICAL FINDINGS

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 ML | | FECAL COLIFORM MPN ORGANISMS/100 ML | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| 1 Effluent | 1 | – | $4.9 \times 10^7$ | – | $4.9 \times 10^7$ |
| 6 Influent | 11 | $10^6$–$10^9$ | $1.9 \times 10^7$ | $10^5$–$10^7$ | $6.9 \times 10^5$ |
| 6 Effluent | 11 | $10^2$–$10^9$ | $8.8 \times 10^5$ | $10^2$–$10^6$ | $2.6 \times 10^4$ |
| 8 Influent | 11 | $10^3$–$>10^9$ | $1.3 \times 10^6$ | $<10$–$10^7$ | $1.0 \times 10^4$ |
| 8 Effluent | 11 | $10^3$–$>10^7$ | $3.3 \times 10^5$ | $<10$–$10^7$ | $1.9 \times 10^3$ |

Table 6.31 shows the results of coliform testing for filtration systems. As observed with the results of no treatment and settling systems, these filtration systems do not significantly reduce the number of fecal coliforms contained in domestic grey water. The measured results of these filtration systems are similar to those for no treatment and settling units, shown in Tables 6.11 and 6.21. By contrast, Oregon field studies of grey water treatment by recirculating sand filters showed fecal coliform reductions of more than three logs.[85]

Bacteria screens were run on two influent and four effluent samples from Unit 6. Test results show isolation of six types of opportunistic bacteria including four isolations of *Klebsiella pneumoniae.* Parasite screens run on one influent and four effluent samples yielded ciliates, flagellates, larvae, and mite eggs, but no known human parasites were identified. A virus screen on one effluent sample did not show any virus isolations.

Bacteria screens were run on four influent and three effluent samples from Unit 8, resulting in the identification of eight types of opportunistic bacteria including several *Klebsiella, Aeromonas,* and *Pseudomonas* forms. Four influent and three effluent samples were tested for parasites. Forms observed during screening included: ciliates, flagellates, larvae, and mite eggs. Two influent samples were screened for virus with no virus isolations.

The results of bacteria, parasite, and limited virus screen work is difficult to interpret because the investigators were not able to introduce a known pathogenic form and then to observe the relative abilities of each grey water system and the subsequent fate of each pathogen. In a field situation, the results of actual households must suffice. In this case, many known bacterial pathogens were identified in treated grey water. Diverse forms of albeit non-pathogenic parasites were commonly identified. It must be presumed that grey water, whether treated or not, is capable of harbouring all pathogenic organisms associated with domestic sewage. Treatment alone did not appear to significantly reduce the level of pathogens entering a disposal system with the systems studied. The addition of a disinfectant would be the most likely method of eliminating pathogens from household grey water; however, disinfection was not employed in any of these systems. The concept of adding a powerful oxidizing chemical such as sodium hypochlorite may have been contrary to the life style and beliefs of individual homeowners or the presence of residual chlorine may have been undesirable for irrigation uses.

## TABLE 6.32
## UNITS WITH FILTRATION: CHEMICAL FINDINGS

| SYSTEM | NUMBER OF DATA POINTS | BOD, mg/l | | COD, mg/l | | TOTAL N, mg/l | | TDS, mg/l | | SS, mg/l | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 1 Effluent | 3 | 300–2,000 | 1,006 | 620–5,400 | 2,575 | 20–280 | 90 | 160–290 | 220 | 590–9,800 | 2,725 |
| 6 Influent | 9 | 90–470 | 228 | 100–770 | 198 | – | 10 | 190–540 | 307 | 50–100 | 77 |
| 6 Effluent | 9 | 120–310 | 212 | 260–510 | 203 | – | 10 | 300–690 | 433 | 10–80 | 40 |
| 8 Influent | 9 | 30–1,500 | 187 | 50–2,300 | 334 | 20–70 | 35 | 70–1,000 | 439 | 10–950 | 83 |
| 8 Effluent | 9 | 30–1,000 | 161 | 60–8,000 | 306 | 10–180 | 26 | 340–1,400 | 564 | 10–250 | 39 |

The results of analytical work reported on Table 6.32 show filtered grey water to be equivalent to results obtained for untreated and settled effluents in all respects except suspended solids (SS). The filtration systems used in Units 6 and 8 reduced particulate matter to levels that approached the 30 mg/l standard for secondary treatment. However, the other measured characteristics of filtered grey water demonstrate a greater similarity to untreated domestic sewage. Aside from particulate removal, the filtration units studied apparently did not provide any measurable degree of wastewater treatment. However, the data from Oregon are quite contrasting in that professionally designed and built units were able to produce effluent qualities of 2 mg/l $BOD_5$ and 10 mg/l SS.

Although limited, the results for Unit 1 demonstrate a special case of a deterioration in water quality due to the addition of excess liquid from the homeowner's waterless toilet, Unit 1. This influence is suggested by the similarity in analytical findings for the toilet liquid and the grey water effluent. The ultimate disposal for this effluent was properly subsurface.

## SECTION 7
## DRY TOILET UNIT DESCRIPTION AND FIELD OBSERVATIONS

### 7.1 LARGE, SLOPED-FLOOR STYLED PROPRIETARY AND HOMEOWNER-BUILT UNITS

The large, sloped-floor proprietary unit marketed under the name Clivus Multrum is shown in Figure 7.10. It is constructed of 3/4-inch fiberglass-polyethane sandwich insulated walls. One homeowner-built unit of similar size and design was included with this group.

The ventilation system consists of an air inlet under the compost storage chamber door; air ducts within the chamber, a vent chute, and a fan. The manufacturer suggests that various models of the system are designed to accommodate from three to ten people. Although it was suggested that the unit will require emptying every few years, the manufacturer indicates that "compost" is produced at the rate of 104 pounds of wet weight per year.

Before assemblying the two halves, the floor and lower air ducts are to be initially covered with a minimum of three bales of thoroughly saturated peat moss and a six-inch layer of leaves, soil, and garden rakings. Air ducts in the shape of an inverted V extend the length of the unit. The manufacturer suggests that these air ducts allow for the aeration of the compost pile by drawing air from the smaller chamber into the larger chamber. A plywood barrier, missing from production models monitored during this study, separates the larger "composting" chamber from the smaller "finished" chamber.

This unit receives toilet and kitchen wastes through separate inlet chutes connected to the larger chamber. One model has one kitchen and two toilet chutes. The chutes are 12 inches in diameter and the exterior is coated with rust- proof dark color paint. An additional six-inch ventilation pipe is located roughly equidistance from the waste chutes. Three fans are available to enhance natural ventilaton.

The manufacturer claims maintenance for the unit is infrequent and limited to the addition of kitchen wastes or some other material high in cellulose to aid decomposition and to prevent "waterlogging." An aluminum porthole on the side of the unit can be used to "settle the pile in case of temporary overloading," to retrieve objects, and to inspect the decomposition process. Apart from this access port, there are no provisions for mixing the contents of the larger waste chamber.

Eight units of this generic type were observed for various lengths of time. The following is a discussion of results gained from field observations as well as analytical and microbiological laboratory data.

### 7.11 Unit A

This proprietary unit was installed in April 1979 on a 2/3-acre coastal site. Start-up differed from that suggested by the manufacturer; a layer of commercial redwood compost was used instead of the recommended peat moss. Bulking agents consisted of daily kitchen wastes and the monthly addition of ashes.

The unit was installed in the basement of a two-story house in close proximity to the groundwater table. Beginning with the wet season, November through June, the groundwater level rose to and flooded the smaller storage chamber. The chamber remained flooded during eight months of field observations. After approximately one months' usage, the two waste piles (toilet and kitchen port) appeared to be mixing well, with no detectable odors and with the temperature at the center of the pile being 30°C. However, by the second month, the users complained of flies and had observed that the toilet wastes were no longer mixing and moving down the slant. Groundwater was noted present in storage area. The users were told by a manufacturer's representative to introduce "natural predators" (spiders) to resolve the fly problem and to periodically prod the pile so that it would slide toward the lower end. At three months, spider webs were noted in addition to the owner's complaint of flies. Groundwater was still present. At four months, anaerobic conditions in the composting chamber were noted by the release of sulfides when the surface was disturbed for the temperature reading. The temperature reading in the center of the pile of kitchen wastes was 26°C. As previously noted, two discrete piles were collecting with no observed mixing. By five months' usage, the unit appeared half full.

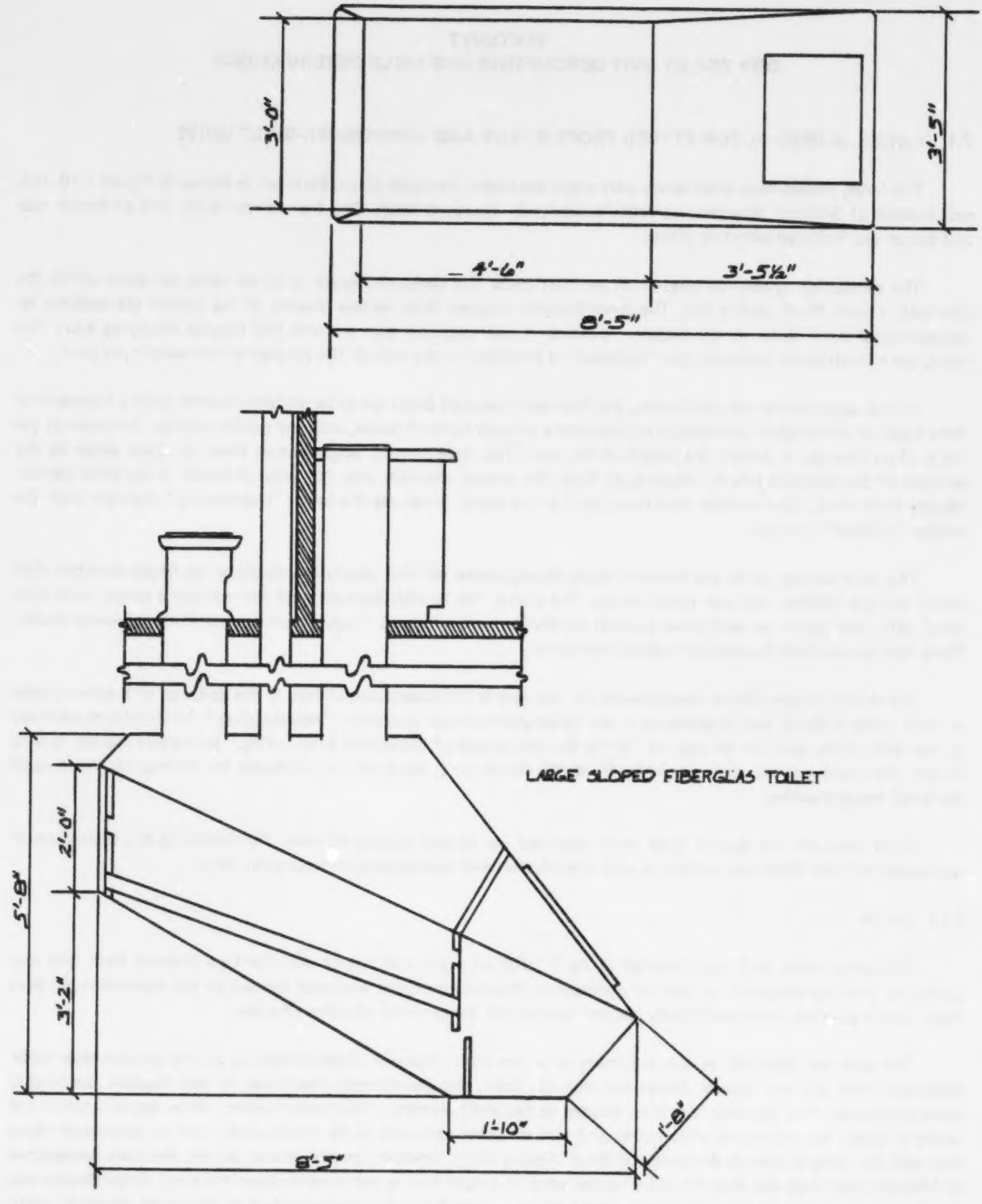

3'-0"
3'-5"
4'-6"
3'-5½"
8'-5"
LARGE SLOPED FIBERGLAS TOILET
2'-0"
5'-8"
3'-2"
1'-10"
1'-8"
8'-5"

FIGURE 7.10 CLIVUS MULTRUM

At six and seven months, the contents were clearly anaerobic, evidenced by strong odor of $H_2S$, the lowering of the pile temperature to 16°C, and the appearance of large quantities of groundwater submerging the storage chamber. The pile appeared wet, and a sample taken from the storage chamber did in fact contain 75 percent moisture. Virus screen results from both field visits yielded positive results for an undetermined type of reovirus; total coliform were $\geq 10^9$ MPN/100 gm for both samples.

By eight months, the groundwater had receded somewhat, and the flies and spiders were not observable. The pile appeared to be mixing but the temperature remained at 16°C.

At nine months' usage, the wastes again appeared in discrete piles and the liquid level in the storage chamber remained unchanged. Beetles were collected from the composting chamber where the pile center temperature remained at 17°C.

The next three months resulted in even lower pile temperatures, 7°–10°C, a constant water level in the storage chamber, sulfide odors, and the appearance of moths and sow bugs in the storage chamber. The liquid in the storage chamber tested positive for reovirus and several forms of opportunistic bacteria, including *Klebsiella*, were isolated. Total coliform for the tested liquid was in the range of $10^4$–$10^5$ MPN/100 ml.

At 12–15 months' usage, the storage chamber remained flooded and anaerobic conditions previously identified persisted.

### 7.12 Unit B

This owner-built 40-cubic foot unit was installed April 1979 on a 1½-acre coastal lot. Start-up consisted of packing slant and floor of finished chamber with a six-inch mixture of garden compost, horse manure, top soil, sand, and lime and six inches of grass clippings. The unit, shown in Appendix A, closely resembled the design of the proprietary unit with the exception of building materials. The unit bottom was a reinforced concrete pad with cinder-block vault walls. The top and doors are constructed of 3/4-inch plywood. The chambers are not baffled.

According to the field sanitarian, bulking materials added to this unit included 2½ to 3 gallons of kitchen/vegetable scraps per week as well as 1 to 2 handfuls of sawdust added after each use.

During the first four months of use, the field sanitarian noted increasing quantities of orange peels, banana skins, and egg shells that did not change in appearance and heavy populations of flying insects that exited both kitchen and toilet ports. The sanitarian then concluded that there were no visible signs of composting. Flies and beetles appeared during the second month and remained for the duration of the study. Anaerobic conditions were clearly present by the fifth month of use as indicated by the release of $H_2S$ when the surface of the pile was disturbed.

At six months, the contents of the unit were hard, dry, and difficult to sample. Considerable updraft through the chamber was noted. The center of the pile was 17°C.

The unit was unused for five months between December through late April. At four and five months of nonuse, samples were taken from the upper and lower ends of the unit. Coliform ranged from $10^5$ to $10^8$, pile temperature was 6°C and the contents were becoming harder. Use resumed during the final two months of observation. Considerable quantities of produce wastes were added; however, some was observed rolling into the finished chamber. The unit was not baffled. Liquids did not build up in this unit. Pile temperature increased slightly when use resumed to 9° and 13°C.

### 7.13 Unit C

This Clivus Multrum Unit was installed February 1979 with an extra midsection. Start-up was with a layer of soil pine sawdust, leaf mold, and goat droppings, not according to manufacturer's direction. Bulking agent was the frequent addition of tree leaves and grass clippings. Monitoring began at five months' usage when a urine odor and spiders were observed. No kitchen-type wastes were observed.

At six months' usage, dried tree leaves and ferns were added to the pile which was at 19°C. A small amount of liquid was observed in the final chamber. At seven months, the owner removed the plywood baffle after it had apparently slipped out of place. No explanation for not replacing it was offered by the owner. The human parasite trichuris was isolated from the composting chamber. At eight months, the liquid buildup in the storage chamber had greatly increased, the pile temperature was 17°C, and mosquitoes were observed within the unit.

The ninth through the eleventh months showed the pile temperature decreasing 16°, 12°, and 10°C. Liquid buildup remained in the storage chamber since the plywood baffle was removed, and the owner observed portions of the fresh pile "avalanching" down into the storage chamber. Sow bugs and spiders resided in the composting chamber. The pH in the storage chamber was between 5.3–5.5.

The owner would not allow site visits during the 14th through the 16th months of use, claiming the unit was not used. At 13 months' usage, the pile temperature remained at 8°C and spiders were present in the storage chamber. Smoke tests were conducted to determine the pattern of air flow through the chambers (with the exhaust fan on). Only upper vents supplied air flow through the larger chamber. No air flow could be detected from the lower vents or within the storage chamber.

The final month of observation of 17 months of operation found the composting area dried out and difficult to sample. A sample from the storage chamber tested within similar ranges for moisture, volatility, and coliform content as did storage chamber samples taken at 6, 11, and 12 months.

### 7.14 Unit D

This Clivus Multrum Unit was installed in March 1977 and start-up was with two feet of peat moss and oak leaf mold on the sloping floor. Bulking agents added included daily additions of kitchen wastes, garden clippings, and a bucket of sawdust every two to four weeks. The owner frequently drained off excess liquid from the unit, diluted it with tap water, and used the mixture to irrigate ornamental landscape. The dry pile was occasionally raked down into the storage chamber.

Observations began at 23 months of continuous use. Flies, spiders, and beetles were present in the larger chamber. At 25 months, 18 gallons of wet solids were removed for additional on-site composting with yard refuse. The center of the finished pile was 19°C. At 29 months, temperatures in the large and small chamber were 20° and 21°C respectively. Both areas had recently been "raked" by the owner. Flies and spiders throughout the study were present. At 30 months, the owner unsuccessfully attempted fly control by using a vapona strip in the larger chamber. Pile temperatures were 21°C in the larger chamber and 25°C in the storage chamber where the moisture content was 39 percent. Similar conditions persisted for the next three months. At 34 months, the pile temperature dropped to 17°C in both chambers. The pH of the larger chamber was 6.5, the storage chamber, 5.3. Moisture content of both chambers was about 60 percent. Smoke testing demonstrated that air was drawn across the storage chamber.

The remaining five months of observation showed the owners continued to rake the unit contents and siphon off accumulated liquid. The storage chamber contents contained 33 to 81 percent moisture; pH ranged from 7.9 to 5.1. The pile temperature varied from 17°–20°C.

### 7.15 Unit E

A Clivus Multrum, supplied by the manufacturer without a baffle, was installed October 1976 at this ½-acre coastal site. Start-up was with a bed of soil and peat. Bulking agents included kitchen wastes and two handfuls of sawdust every two to four days. The owners stated that approximately 25 to 40 gallons of liquid were pumped out of the unit every 2 to 3 months. Flies, sowbugs, and moths were observed throughout the study. The owners did not turn the pile. Bucketfuls of wet solids were removed for subsurface burial around grapevines about every six months. The kitchen pile showed temperatures of between 18°–20°C and pH levels between 5.0–5.5.

At 34 months, a pump and spray nozzle were installed to recirculate the liquid from the storage chamber back over the contents of the larger chamber. It was also noted that although the exhaust fan was on 16 hours per day, the squirrel cage turbine vent was located about 7 to 10 feet below the high point of the home's sloped roof. The moisture content of the larger chamber was between 70–80 percent for the next three months. The owner observed that the pile had settled and was sliding into the storage chamber. At this time the storage chamber became permanently submerged in the liquid buildup. Final samples for remainder of study were taken by pumping the liquid into the larger chamber to expose the solids in the storage chamber. Conditions remained unchanged for remainder of study. Larger chamber pile temperatures ranged from 13°–21°C. The liquid and solids in the storage chamber range ranged in pH between 4.5 to 5.5. Owner had frequent complaints of moths and flies and reportedly sprayed every few days with pyrethron.

### 7.16 Unit F

This Clivus Multrum Unit was installed in a guest house on a one-acre coastal site in November 1977. Start-up was with garden soil, leaves, and peat moss. Bulking materials included daily kitchen wastes and weekly addition of one pound of peat moss.

Observations began at 16 months' usage with mites, moths, flies, and spiders in larger vault and liquid filling storage chamber. Owner had recorded weekly temperatures since installation for both toilet and kitchen piles which showed kitchen side consistently warmer. This suggested little natural mixing occurred in the larger chamber. Study observations did confirm this relationship, but not the magnitude of the readings. Older owner readings ranged from 10°–35°C with as much as 40° difference between kitchen and toilet piles while study observations recorded from 9°–26°C with only 2°–3° difference. Finished samples analyzed from this unit may contain part or all peat moss and were continually inundated with built-up liquid.

### 7.17 Unit G

This Clivus Multrum Unit with two toilet ports and an additional midsection was installed October 1979 on a five-acre mountain site. Start-up consisted of a 50-50 soil/peat moss mixture, grass clippings, and earthworms. Bulking agents included kitchen wastes and a monthly bucket of peat moss. Owners sprayed weekly with pyrethin to control flies. Liquid was collecting in storage chamber when observations began. It was noted that the contents of the larger chamber were frequently turned and temperature readings after turning increased from 16°C to 23°C. Over nine months' observation, this unit continually reflected intensive maintenance and care. Temperature reading could not be taken every month due to lack of access; however, three of the last six months recorded readings between 21°–22°C.

### 7.18 Unit H

This Clivus Multrum Unit was installed November 1979 on a seven-acre mountain site. Start-up was by the addition of sawdust grass clippings, peat moss, and soil containing worms. Bulking agents were daily kitchen wastes and monthly addition of sawdust and/or grass clippings. The pile was infrequently manually turned.

About one foot of liquid was observed after three months' use which was subsequently handled by packing the storage chamber with peat moss which was periodically removed for disposal. When owners did not replace peat moss, the liquid quickly reappeared. Pile temperatures ranged from 12°–18°C.

## 7.2 LARGE, SLOPED-FLOOR PLASTIC UNIT

The large, sloped-floor plastic proprietary unit, Toa Throne, is similar to, but smaller than, the Clivus Multrum. The manufacturer suggests that four to six people can be accommodated. The Toa Throne has only one waste chute, the toilet stool opening, where waste material drops onto a row of slanting conduits above an air staircase. The air staircase allows air to enter the chamber bottom where an electric blower maintains circulation up through the chamber and out the ventilation chute. The slanting conduits are to prevent the wastes from packing together, and to allow the wastes to drop onto the staircase where it slides towards the chamber bottom.

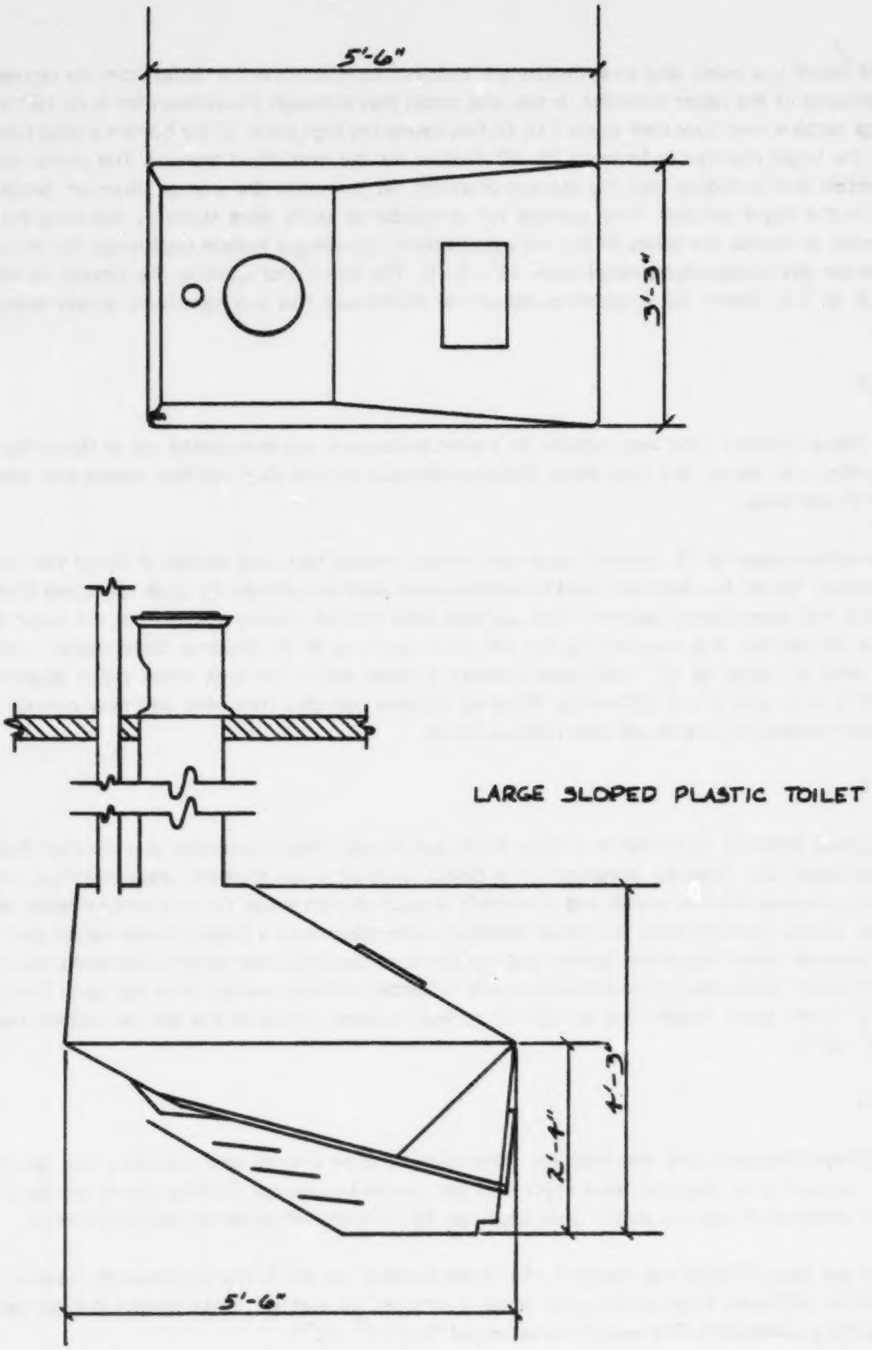

5'-6"
3'-3"
LARGE SLOPED PLASTIC TOILET
1'-3"
2'-4"
5'-6"

FIGURE 7.20 TOA THRONE

The start-up and maintenance procedure suggested by the manufacturer is as follows. Start-up is with a bed of peat moss, and two pounds of lime composit soil or bark humus. Maintenance is described as infrequent, "a handful of lime into the toilet opening from time to time every year." The addition of organic kitchen wastes are suggested because the organic additions will "fluff" or aerate the pile.

The manufacturer suggests the end product should be composted an additional six months as a precautionary measure. Three units of this generic type were observed.

### 7.21 Unit I

Toa Throne was installed at a 0.7 acre mountain site October 1976. Start-up was by the addition of peat moss, yard compost, and grass clippings. Kitchen wastes and wood shavings were added weekly. A small amount 0.5 to 1 pint of wood ash was added every 6 to 8 weeks. One cup of sawdust was added after each use. Because heat was not generated and the pile size consistently increased, the owners concluded that the excrement was not properly composted. The owners indicated that any solids removed from the finished chamber would be buried on site.

During the first 6 months of observation which corresponded to months 28–34 of use, pile temperatures ranged from 16°–21°C. The pile appeared neither to be reducing nor to be moving towards the bottom of the chamber. Small flying insects, spiders, and signs of rodents bothered the owners. At 34 months of usage, the pile was quite hard and the chamber very full. The owners had stopped adding plant material in an effort to control insects. Months 35 and 36 showed that the addition of water and sawdust had helped to soften the waste chamber contents, a well-developed cone indicated no internal mixing or movement was occurring. No finished material had appeared in the final chamber to date. At 40 months of use, the chamber was entirely filled, the air staircase appeared to have collapsed under the weight of the pile, and liquid filled the chamber end up to the access door opening.

The distributor agreed that there might be a structural defect with this unit and had offered to replace it with a unit of another design.

### 7.22 Unit J

This proprietary unit was located on a 200-acre coastal site. Start-up in 1977 included soil and peat moss. Kitchen-type wastes including wastes from a one-time wine-making venture were added regularly. Observations began at about two years' usage. Flies appeared when wine-making wastes were added; the pile temperature was 22°C. During the next few months, pile temperatures decreased to 7°C, the flies were absent, and the chamber contents had apparently been raked.

At six months' observation, the frequency of use increased as did the pile temperature to 15°C. Flies and spiders were observed in bathrooms. Owner reportedly was raking the contents and had stopped garbage additions because the unit was filling too quickly. He was advised to continue refuse additions. Liquid was collecting next to access door and continued to the last months of observation. Owner had decided to abandon unit in favor of a flush toilet and subsurface disposal leach field.

### 7.23 Unit K

This proprietary unit was installed June 1978 on this one-acre coastal site. The unit was located at a group residence site and had a counter attached to register each use. About six uses per day were occurring when observations began. After eight months of use, a liquid buildup was noted and the fact that the additional kitchen wastes had recently been discontinued to control the fly problem. The center of the pile was 24°C.

By the next month, the pile had turned anaerobic, sulfide odors were noted, and the center temperature had dropped to 14°C. A liquid overflow had occurred through the access door prior to the site visit and about 16 gallons of liquid were removed. Three weeks later, the fresher pile had been turned and a moisture absorbent added. The pile center was now 26°C and the pH was 5.5. The lower portion of the vault, however, had sulfide odors and contained about 25 inches of standing liquid.

The fourth month of observation noted that the use rate remained constant at about six per day. The vault, however, appeared anaerobic with sulfide odors present and with the pile center at 24°C and pH of 7.8. At five months, both ammonia and sulfide odors were detected in the vault. The pile was at 21°C with a 7.3 pH. About eight to nine uses per day were occurring.

The remaining 12 months of observation demonstrated unchanged conditions. Overflows occurred frequently; mice, rats, and skunks invaded the exterior insulation, anaerobic symptoms, including presence of insects, persisted within the vault. As the vault filled, the unit walls bulged and the air baffles collapsed under the weight of the excrement. The site manager determined that although the unit might function for one or two people, it did not meet their needs, and that a low volume flush toilet would soon replace the unit.

### 7.3 VAULT PRIVY

The vault privy is a Vietnamese design, owner-built unit containing side-by-side chambers made of impervious material above which a stool or squat plate is housed. Units are constructed of cement, concrete blocks, brick, stone, or wood. The chambers each have hinged access doors which allow the pile to be turned, removed, or for the addition of bulking agents. Two different modes of operation are suggested for the vault privy. The following summarizes techniques used for aerobic operation.

Start-up is with a 12-inch layer of hay, sawdust, or peat moss. A one-pound coffee can of the same carbonaceous material is added with each use. Suggested maintenance includes monthly turning to mix and aerate the pile. With average use, the chamber fills in six to nine months. When full, either the contents are moved to the empty side for further stabilization or the toilet seat is relocated over the empty chamber. In either case, the full chamber is sealed from further additions and allowed to decompose while the empty side is put in use using the same start-up techniques. When this chamber fills, the stabilized side is removed for final disposal and the cycle repeated.

McMichael and Rybczynski[75] have each reported about the anaerobic vault process. The Vietnamese use anaerobic techniques for operating this system which are as follows. Urine separation is practiced in Vietnam, and the unit is used primarily for defecation. The start-up procedure is the same, the bottom is covered with a layer of earth or other available absorbent. After each use, the feces are covered with available bulking agent which is intended to absorb moisture and to control odors. When the compartment is two-thirds filled, the contents are leveled and the remaining space is entirely filled with additional bedding material. All openings are tightly sealed to create anaerobic conditions, and the contents reportedly are vector and pathogen-free in about 45 days.[75]

Five units of this generic type, each site diagramed in Appendix A, were observed with the following comments.

#### 7.31 Unit L

This two-chambered vault unit was owner-constructed, mid-1976, of rock and mortar on a concrete slab floor on a 20-acre coastal site. A shingled wood frame structure was above the vault. The toilet chute was stationary on this unit and the vault chambers were separated by a partial-short divider wall.

Start-up was with a layer of pine and fir sawdust. One pint of sawdust was added after each use and the contents were manually turned once each month. Earthworms were introduced to the older pile which was allowed to stabilize for six to eight months. The finished solids were then removed to further decompose within a garden compost pile.

Observations began after two years of use with the note that pile temperatures were 12°–14°C and that the aging side looked very wet and contained pooled water. The following two months noted higher temperatures in both the fresh (27°, 31°C) and aging (22°, 18°C) piles. A small number of flies were noted in or near the vault area. The pH of the fresh pile was 7.2, the aging pile 5.7.

At the third month of observation, the owner had removed the aging material and replaced it with the contents of the in-use side. The newly aging material was then sampled monthly for five months. Total coliform remained relatively constant at $10^7-10^6$ MPN/100 ml as did other physical parameters, pH, percent moisture, and total and volatile solids. The temperature, however, declined from 21 to 9°C over the 5-month period. The fresh side also showed a declining temperature over the same time period to 13°C. This decline in temperature which paralled ambient air temperatures from July through December was one indication that actual composting activity was not occurring.

When observations resumed after a three-month rainy season, groundwater had intruded into the vault at the wall-floor seam. Although both piles looked well-turned, neither pile generated temperatures above 20°C for the remainder of the study.

### 7.32 Unit M

This double-vault privy was constructed of poured in-place concrete with a wood structure above on a 32-acre coastal site in May 1978. Start-up consisted of a layer of fir sawdust. About one pint of sawdust was added after each use. Observations began after ten months of use. The 3-month-old aging pile was 13°C and the in-use side 22°C. The piles were not regularly turned and appeared very moist. Flies, spiders, and maggots were present. Condition remained similar during the next four months except that ants soon invaded both chambers.

The contents of both chambers were removed between site visits. The in-use side filled during the next four months, the pile temperature dropped from 22°C to 12°C, and the unit appeared to have received little or no maintenance.

The in-use contents were allowed to stabilize by the owners when the toilet seat was moved to the empty side. The temperature of both piles was 8°C. The aging side was observed for the next five months. The coliform content remained in the range of $10^9-10^7$ MPN/100 ml. The physical parameters, pH, moisture content, and total and volatile solids also remained unchanged. The sixth-month site visit found both chambers empty as had occurred earlier in the study.

### 7.33 Unit N

This double vault, owner-built system was constructed with poured in-place concrete and with a wood structure above on a six-acre coastal site in 1975. Start-up was with a layer of straw, bulking agents were sawdust after each use and semimonthly addition of ash. The piles were turned monthly, aged about six months, then removed to a garden compost pile for further stabilization before final disposal.

Observations began after approximately four years of use. The in-use side was filled and both sides were very wet due to groundwater infiltration and to a plugged bottom drain. Pile temperatures were 15°–17°C. The second month of observation noted the previous in-use side had been sealed and was now aging. This pile temperature was 29°C and the pH was 8.9 possibly due to the recent addition of wood ash. The next five months showed the temperature declining from 29°–22°C, the coliform ranging from $10^6$ to $10^7$, and all other physical parameters remaining virtually unchanged. The only unusual observation was that several toads took up residence in the aging chamber. The fresh chamber maintained temperatures between 28°–34°C during this time sequence.

A new aging pile was then established from the contents of the fresh chamber. The in-use side now contained fir sawdust instead of the redwood previously used. The two-day-old aging side had a pile temperature of 16°C. This aging side was observed for five months before removal prior to site visit at six months. Physical and biological conditions again remained unchanged. Groundwater appeared to infiltrate unit through bottom drainpipe. Although the toads left, a colony of ants replaced them. During this "aging" process, the fresh side continued to exhibit temperatures between 29°–31°C.

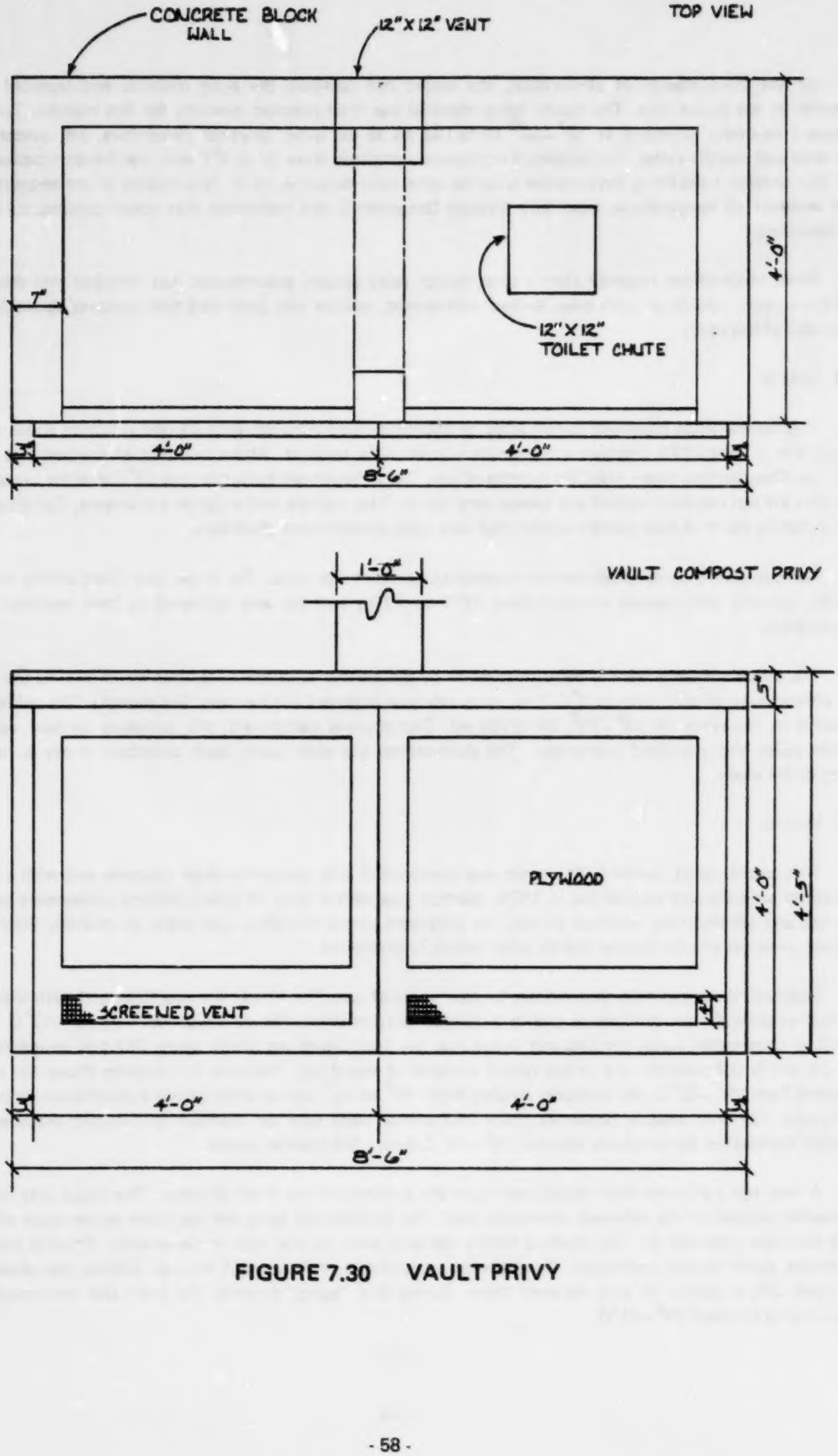

CONCRETE BLOCK WALL
12"X12" VENT
TOP VIEW
7"
4'-0"
12"X12" TOILET CHUTE
3"
4'-0"
4'-0"
3"
8'-6"
1'-0"
VAULT COMPOST PRIVY
3"
PLYWOOD
4'-0"
4'-5"
SCREENED VENT
4"
3"
4'-0"
4'-0"
3"
8'-6"

**FIGURE 7.30 VAULT PRIVY**

### 7.34 Unit O

This owner-built double vault unit was constructed of cinderblock on a concrete foundation with plywood structure above on a five-acre coastal site in early 1978. Start-up was with a layer of sawdust. Bulking agents were fir and redwood sawdust added after each use. The piles were turned monthly and the aged material was buried on site. Observations began after about one year of use. The users advised samplers that they had a confirmed case of *Salmonella* five months earlier and had sealed off the in-use side at that time.

The ten-month-old aging side was sampled twice on two successive months for *Salmonella* with no isolations. Coliform levels were at $10^3$ MPN/100 gm for both samples. However, at 12 months, the fresh side was submitted for and *Salmonella arizona* was positively isolated. Coliform content of this sample was $10^9$ MPN/100 gm. Both fresh and aging pile temperatures at this point were 18°–19°C. The contents of the in-use side became the aging side shortly after this sampling.

The new aging side was retested at 3, 4, 6, 7, and 8 months. Although *Salmonella* forms were not isolated, at least ten forms of opportunistic bacteria were isolated, including *Klebsiella* and *Serratia*. The coliform content of these samples ranged between $10^5$ to $10^7$ MPN/100 gm. Parasite egg and larval forms were also noted present. Pile temperatures remained between 8°–11°C during this 8-month sequence.

### 7.35 Unit P

This double vault owner-built unit was constructed of cinderblock on a concrete pad with a wooden enclosure above on a ten-acre coastal site about March 1977. Start-up was with four-inch layer of straw, and about one pint of fir sawdust was added after each use. The fresh pile was turned monthly, and the stabilized pile was intended for removal at about six-month intervals for on-site burial. The toilet seat was moveable on this unit.

Observations began at two years of use. Odors, beetles, flies, and spiders were noted present. The aging side had been stored for 2 months and had a pile temperature of 20°C. At four months, the aging side was 12°C and mice were present. At about five-months storage, the owners resumed use of the aging side without removing the aged solids.

This same practice was repeated twice at about five-month intervals during the remaining period of observation during which the coliform content decreased by about four logs. The pH value changed from the 6–8 range to 4–5, and the pile temperatures varied between 16°–20°C. Three samples of two- to three-month-aged solids were screened for bacteria with eight types of opportunistic bacteria identified including *Klebsiella*. Two of these samples were also screened for parasites. No known human parasites were found; however, live larvae were noted in both samples.

## 7.4 BOX-LIKE TOILET WITH TOPPING BAR

This proprietary unit sold under several names, including Mullbank, and is a smaller unit that fits entirely within the bathroom. It was used in several instances as a retrofit for the traditional porcelain appliance fixture. This unit has thermostatically controlled heating coils, an automatically operated ventilating fan, and a manually operated topping bar or stirring arm that distributes the wastes. The manufacturer suggests the unit can accommodate up to five–six people, even though generic descriptions suggest a capacity no more than two.

The manufacturer supplies an initial quantity (20 pounds) of peat that is placed in a layer above the heating coils. Wastes build up on this peat bed and are eventually scraped through the coils by the user into a collection tray. The manufacturer suggests the unit should always be half full, and that it will require emptying on a yearly basis.

An intensive maintenance program is described for this unit. During normal use it is suggested that the bathroom be kept warm so that warm air is drawn through the unit by its ventilating system; that the waste pile be manually spread throughout the unit at least once per month; and that the waste pile be periodically covered with a thin layer of grass, leaves, peat moss, paper, or kitchen wastes to "increase both absorption capacity and aeration." If use should be significantly reduced or discontinued, the manufacturer suggests that water be spread over the waste pile, especially the rear of the pile, and that the electric power be switched off during long periods of nonuse. Four units of this generic type were observed.

### 7.41 Unit Q

This Mullbank was installed into a specially-designed bathroom of a dwelling built on a 1.4-acre mountain lot in the fall of 1976. The unit was placed so that the exterior step and collection tray compartment are below floor level. The exposed stool compartment was then at a level similar to the porcelain toilet fixture. Access to the collection tray was by means of a lift-up hatch in front of the unit.

The first site visit occurred at approximately 2½ years' use. The collection tray was filled with liquid, the unit unplugged, and the topping bar was broken. The pile was in a well-defined cone with a few flies in the collection tray. The "finished" solids looked no different than the fresher material, including discrete pieces of toilet paper.

The next eight months of observation found little solids or liquid in the collection tray and temperatures between 16°–26°C near the interior coils of the unit. The fan and heater reportedly ran continuously. No odors were noted. Sawdust was reportedly added after every use. Three finished and one fresh sample were submitted for coliform analysis with results ranging from $10^7$ to $10^9$ MPN/100 gm.

The remaining eight months of observation were with a rental family who added two handfuls of sawdust to the system on a daily basis and who also ran the fan continuously. Within the first month of occupancy, one of the users had a confirmed case of viral hepatitis. Site visits had occurred within two weeks before and after the diagnosis was made. Viral analyses using several experimental cell lines failed to isolate the hepatitis virus; however, isolations of the hepatitis virus have never been made to date in a laboratory setting. Coliform levels of both samples were $10^7$ MPN/100 gm. The pile temperature was 22°C. By the second month of tenant use, the collection tray was filled to overflowing with liquid and the pile temperature had dropped to 14°C. The users indicated that the internal contents had to "be moved with a stick." They did not appear to know how to operate the system. By the following month, a service representative had completely emptied the unit and had begun with a new layer of start-up material.

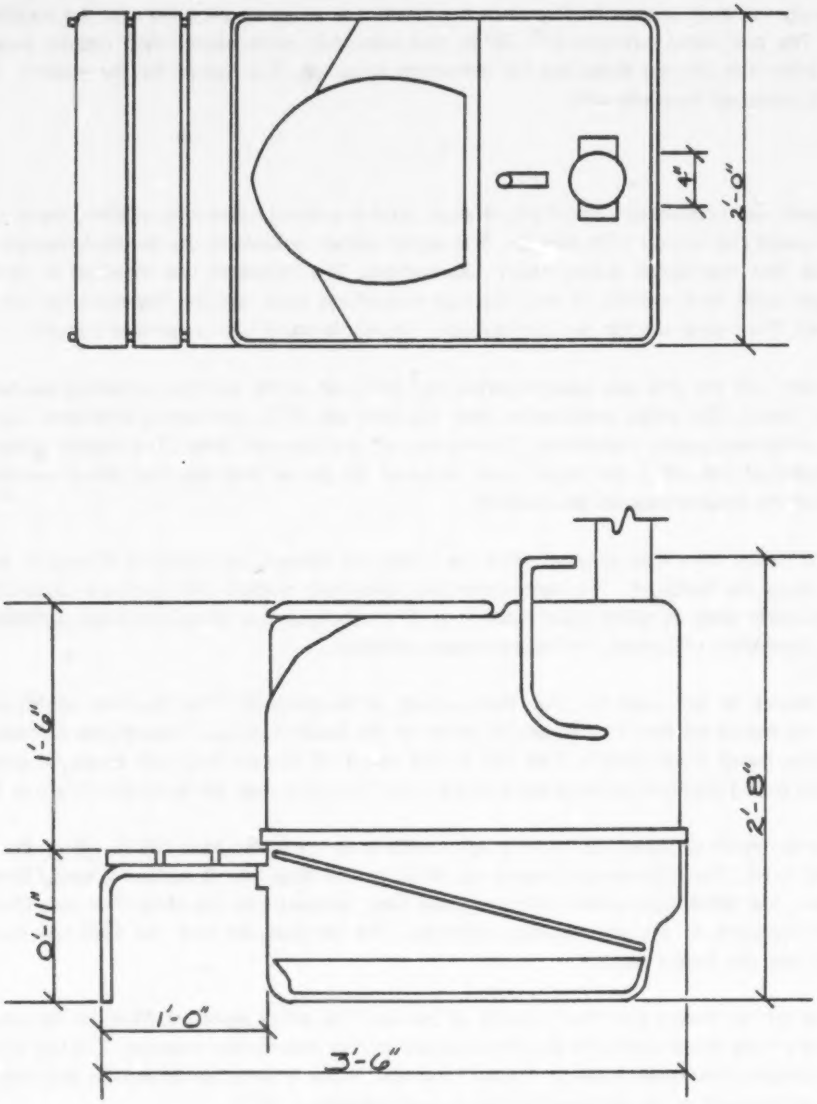
The following four months were a repeat of the tenants' earlier experience. No solids were in the collection tray, samples were obtained by scraping material from the coil area. The user complained about odors even though the fan ran continuously and about having to use a stick to move the mass within the compartment.

### 7.42 Unit R

This Mullbank was installed on a 40-acre coastal site inside a home to supplement a nearby pit privy in June 1979. Start-up was according to the manufacturer's directions.

Observations began at six weeks' use with the unit half full, the collection tray filled with liquid, and no solids fell or were scraped through the coils. A manufacturer's representative told the owners to use the scraper furnished with the unit to bring through peat moss bedding and solids. Flies were not eliminated by insecticide sprays. Solids near the coils were at 33°C. Bulking agents were not routinely added. Performance remained similar for the next three months. The owner expressed concern about the presence of flies and about the fact that the coil did not heat the mass to the 50°C temperatures as claimed. During this three-month time period, two liquid samples were analyzed for coliform content, both had $< 10^4$ MPN/100 ml. Two samples of solids from the toilet box were screened for bacteria, parasites, and virus. Coliform varied from $10^8$ to $10^3$ and no virus or bacteria were isolated. Viable eggs and larvae that resembled atypical human hookworm were noted. After consultation it was determined that they were not human hookworms.

The next 6 months of observation noted temperatures between 25°–40°C being reached in the solids near the heating coils. The sampler noted that finished solids nearly always had to be scraped from the coil area and were rarely present in the collection tray. Coliform varied in the liquid from the collection tray from between $10^2$–$10^4$ MPN/100 ml, and between $10^2$–$10^6$ MPN/100 gm from the scraped solids. Larvae and cyst-like structures continued to be isolated from both solids and liquid. No viruses were isolated from one liquid and two solid samples.


4"
2'-0"
1'-6"
2'-8"
0'-11"
1'-0"
3'-6"

BOX-LIKE HUMUS TOILET WITH TOPPING BAR

FIGURE 7.40 MULLBANK

The final two months of observation had the users adding a handful of sawdust after each use. The amount of liquid was reduced in quantity but was still present. The reduced quantity of liquid noted was probably due to the family reducing their usage of their indoor facility since the family had a nearby pit privy and the weather was warmer as summer began. The pile varied between 27°–38°C, and anaerobic odors were noted present near the home and within the unit when the pile was disturbed for temperature reading. The handle for the topping bar was worn and partially removed from the unit.

### 7.43 Unit S

This Mullbank was installed as a retrofit for a flush toilet in a rental home with a failing septic tank-soil absorption field. This coastal site was on a 1/20-acre lot. The septic system remained in use to accommodate household grey water, which was also monitored during study observations. The Mullbank was installed in October 1978 and observations began after four months of use. Start-up procedures were lacking, the contents were never mixed, turned, or emptied. The heater and fan ran continuously. Ammonia odors were present at the unit.

By 10 months' use the unit was approximately half full with solids, and the collection pan had been filled to overflowing with liquid. The solids temperature near the coils was 32°C, and strong ammonia odors were present within the unit, which was poorly maintained. The fan was off and the shell dusty. The tenants refused to dispose of tray contents. Some of the solids and liquid were removed by the sampler but that which remained was shortly "abandoned" when the tenants vacated the dwelling.

The fan and heater were disconnected while the house was cleaned for a new set of tenants, everywhere, that is, except in or about the Mullbank. The contents of the toilet vault quickly dried out to a cement-like consistency with quite recognizable wads of toilet tissue stuck in it. The collection tray contained black, grit-like solids floating in liquid. After two months of nonuse, the house was again occupied.

The new tenants did not want to "see, think about, or handle unit." The fan ran continuously and warm temperatures in the bathroom were evaporating some of the liquid build-up. Tenant did not use the unit much and strongly discouraged guests from using it. At the end of the study, the unit was about 80 percent full, with about 1½ gallons of liquid in collection tray and strong ammonia odors present at the unit. The solids near the heating coils were at 28°C.

By the fourth month of tenant use, sulfide odors were apparent from about 100 feet from the residence up to and including the toilet. The toilet compartment was filled to seat level with excrement; liquid filled about half of the collection pan. No solids had either fallen or had been scraped into the collection pan. Neither owner nor tenant had taken measures to get unit working correctly. The temperature near the coils had dropped to 20°C. Shortly after site visit, the tenant vacated.

The fan was left on during the three months of nonuse. The solids again solidified to the point that it could not be penetrated by the metal shaft of a dial thermometer during temperature readings. The last month of observation found that attempts had been made to "revive" the unit. Water was added and the pile probed to break up the mass. Odors were present at the unit and the internal temperature was 35°C.

Samples of solids and liquid analyzed throughout the study showed that little change or stabilization had occurred. As temperatures declined, coliform content increased.

### 7.44 Unit T

This Mullbank was installed on a retrofit for a flush toilet within a rental home with a failing septic tank system in May 1979. The site was a 1/15-acre coastal lot with a cesspool serving household grey water.

Observations began at three months of system use. Start-up was according to the manufacturer's directions. The tenant added kitchen refuse, wood ash, and plant cuttings on a weekly basis. The unit was used about every other day. The fan ran only when odors were noticed by the user, but heater ran continuously. The temperature near the coils was 33°C.

The next 6 months of observation showed the temperature between 24°–35°C and no liquid in collection tray. Water was frequently added to solids and flies did not seem controllable with sprays or insecticide strips.

During the tenth month of use, the tenant rewired the fan and switch to allow for manual control. During the remaining four months of observation, higher temperatures were noted when the tenant was home, 37°–40°C; however, lower temperatures were noted when the tenant was absent, 22°–23°C and presumably the manual control set too low or off.

### 7.5 BOX-LIKE TOILET WITH ROTOR

The Bioloo is one type of proprietary box-like toilet that has an internal rotor. This unit is similar in size and design to the Mullbank unit. It is constructed of polyethylene and has a steel pasteurization tray and rotor. It contains an air inlet next to the seat and a fan inside the chamber. The manufacturer claims unit will accommodate up to four people. Suggested start-up is with a bed of peat moss in the storage chamber which is to be replaced when the unit is emptied. Small quantities of kitchen wastes can be added. The pasteurization tray should be emptied bimonthly.

The large excrement chamber provides storage and primary heat treatment at 35°C. With each use the rotor is turned to mix the pile. When the storage chamber fills, a small door between the chamber and "pasteurization" box is opened, the rotor is turned a few times to load wastes into the box, the door is then closed. A manually-activated timer switch starts a six-hour heat treatment cycle which is intended to bring the wastes to 70°C. The tray contents may subsequently be disposed of after this cycle.

Four of these proprietary units were observed during the study.

### 7.51 Unit U

This Bioloo was installed to replace a flush toilet at a home with a failing septic tank system about June 1979. The home was on a 1/15-acre coastal lot. The unit was started according to the manufacturer's directions and the users added one cup of peat moss and turned the rotor after each use. The solids were removed from the pasteurization tray on a monthly basis for off-site disposal at an approved dump site.

Observations began at six weeks' use with the unit experiencing an overload which had been cleaned out by a septic tank pumper immediately prior to the site visit. Odors were apparent at a distance of about 100 feet to and including the unit.

The next four months of cautious use had the following observations. Flies and maggots were present inside the unit, as were anaerobic odors when rotor was turned, and temperatures near the heater varied between 37°–59°C.

The remaining six months of observation noted temperatures between 50°–60°C and coliform levels in three finished samples of $< 10^2$ MPN/100 gm. The users experimented with various combinations of bathroom heat, baking soda additions, and fan operation to control odors, liquid evaporation, and flies. Nonetheless, odors and flies persisted.

The owners viewed the unit as a temporary measure until the community was sewered.

### 7.52 Unit V

This Bioloo was installed as a retrofit toilet on an upstairs rental apartment with a failing cesspool in April 1979. The two-story unit was located on a 0.11-acre lot about 200 feet from the Pacific Ocean. Start-up was according to the manufacturer's directions. Peat moss was added after each use, kitchen wastes occasionally. The pile was sprayed with water periodically to allow for easy turning with the rotor.

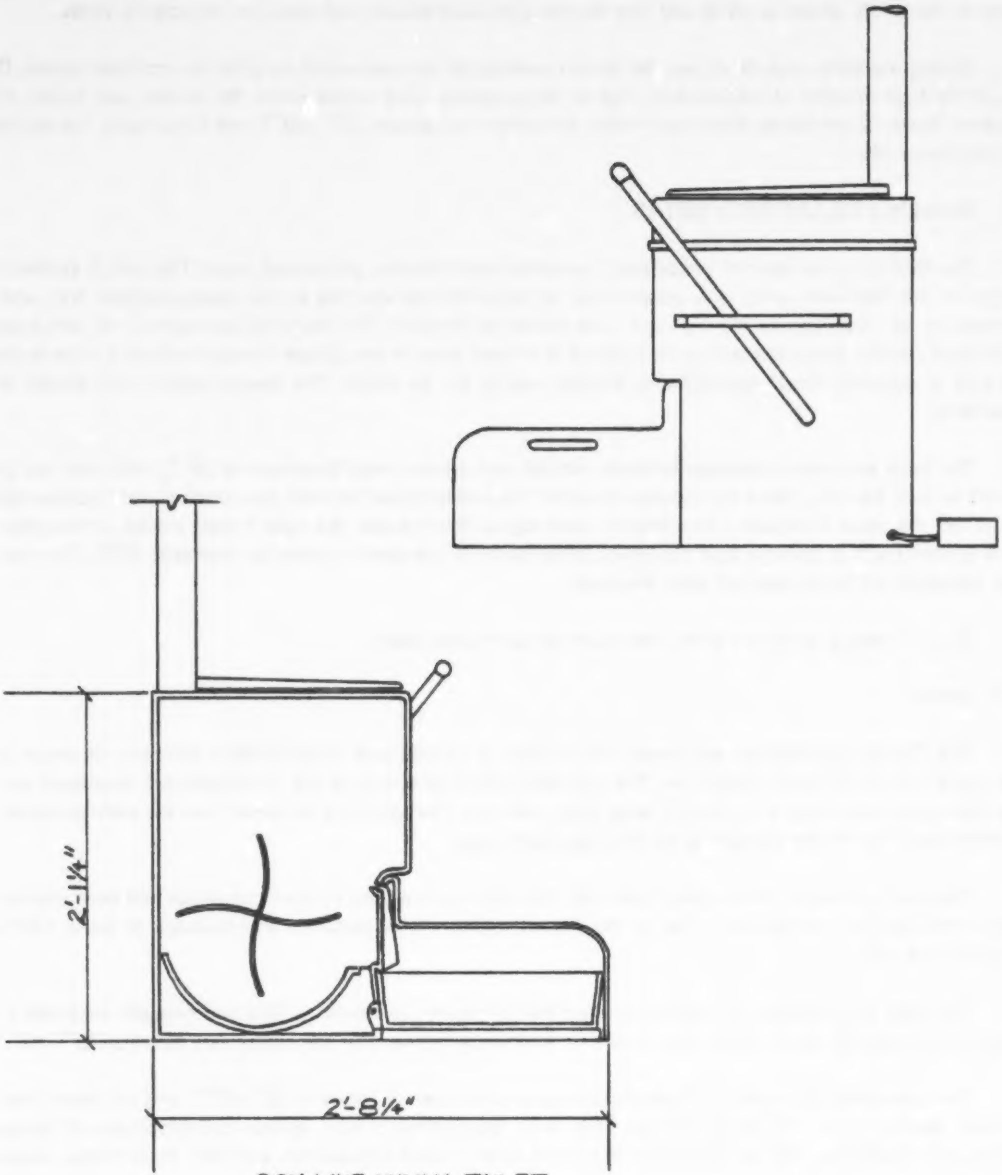

2'-1¼"
2'-8¼"
BOX-LIKE HUMUS TOILET
WITH ROTOR

FIGURE 7.50 BIOLOO

Observations began with the fourth through the sixth month of system use. Temperatures near the heating unit varied between 48°–58°C. Ammonia odors were present near and within the toilet. Coliform content of the mixed contents varied from $10^6$ to $10^2$ MPN/100 gm. The pH ranged between 8.0–8.5, the moisture about 80 percent, and the volatility about 68 percent.

During the next eight months, the tenant experimented with different techniques for obtaining a final product. Internal temperatures ranged from 45°–60°C unless the pasteurizing unit was on in which case lower temperatures, 33°–39°C, were noted. At about midcycle during separate site visits, the pasteurizing unit produced temperatures of 63°, 54°, and 50°C. If the contents of the tray were "soupy," the tenant added peat moss before the heat cycle. The finished contents of the tray were put into plastic bags and either retained for garden compost pile or placed in the garbage can. The coliform content from "pasteurized" samples ranged from $10^4$ to $< 10^2$ MPN/100 gm, and a nonviable larvae was noted from one sample. The average moisture content of the end product was 83 percent, the average volatile solids content 68 percent.

### 7.53 Unit W

This Bioloo is a retrofit for a flush toilet in the lower flat of the same house that Unit V is located, 200 feet from the Pacific Ocean. It was installed October 1979 and start-up was according to the manufacturer, which was somewhat difficult since the instructions were supplied only in Norwegian. Fortunately, the owner had marginal knowledge of that language. The owner added two cups of a sawdust-peat moss mixture on a monthly basis and mixed the solids with the mechanical rotor after each use. The fan was operated only when there was no wind draft. Problems with condensation in the venting system were corrected by relocating the piping within the house.

During eight months of observations, odors were only present during the "pasteurization" cycle. Internal heating coil temperatures ranged between 49°–62°C. The solids occasionally looked wet but liquid did not collect within the unit. Four samples of solids that had undergone various lengths of the pasteurization cycle were analyzed. Coliform levels were $10^4$ to $< 10^2$ MPN/100 gm. The moisture content averaged 79 percent, the volatile solids, 67 percent.

The owner retained the finished solids for gardening uses.

### 7.54 Unit X

This Bioloo was installed at a seasonally-occupied home on a 1/3-acre mountain lot during the summer of 1978.

This site was observed for an eight-month period during which time strong odors and a liquid buildup problem were noted. A short-term increase in use created a soggy pile which was difficult to turn. The rotor handle reportedly had broken three times and was near the fourth when this overload occurred. Finished solids were buried on-site.

Two samples of mixed solids had coliform $10^6$ and $10^4$ MPN/100 gm, average moisture of 65 percent, and an average volatile solid of 63 percent. One pasteurized sample contained $10^5$ coliform, 70 percent moisture and 68 percent volatile content.

## 7.6 DRUM PRIVY

The drum privy consists of a 55-gallon drum fitted tightly to the subfloor of an enclosure, in which a toilet chute is sealed through the floor over the drum. Support beneath the drum can be provided with jacks or turnbuckles.

A vent extends from as high on the chute as possible to a point above the roof. Aerator tubing, usually perforated PVC, may enter through the already existing hole at the drum's side and extend upwards through the center of the barrel. One pint of carbonaceous material is added after each use.

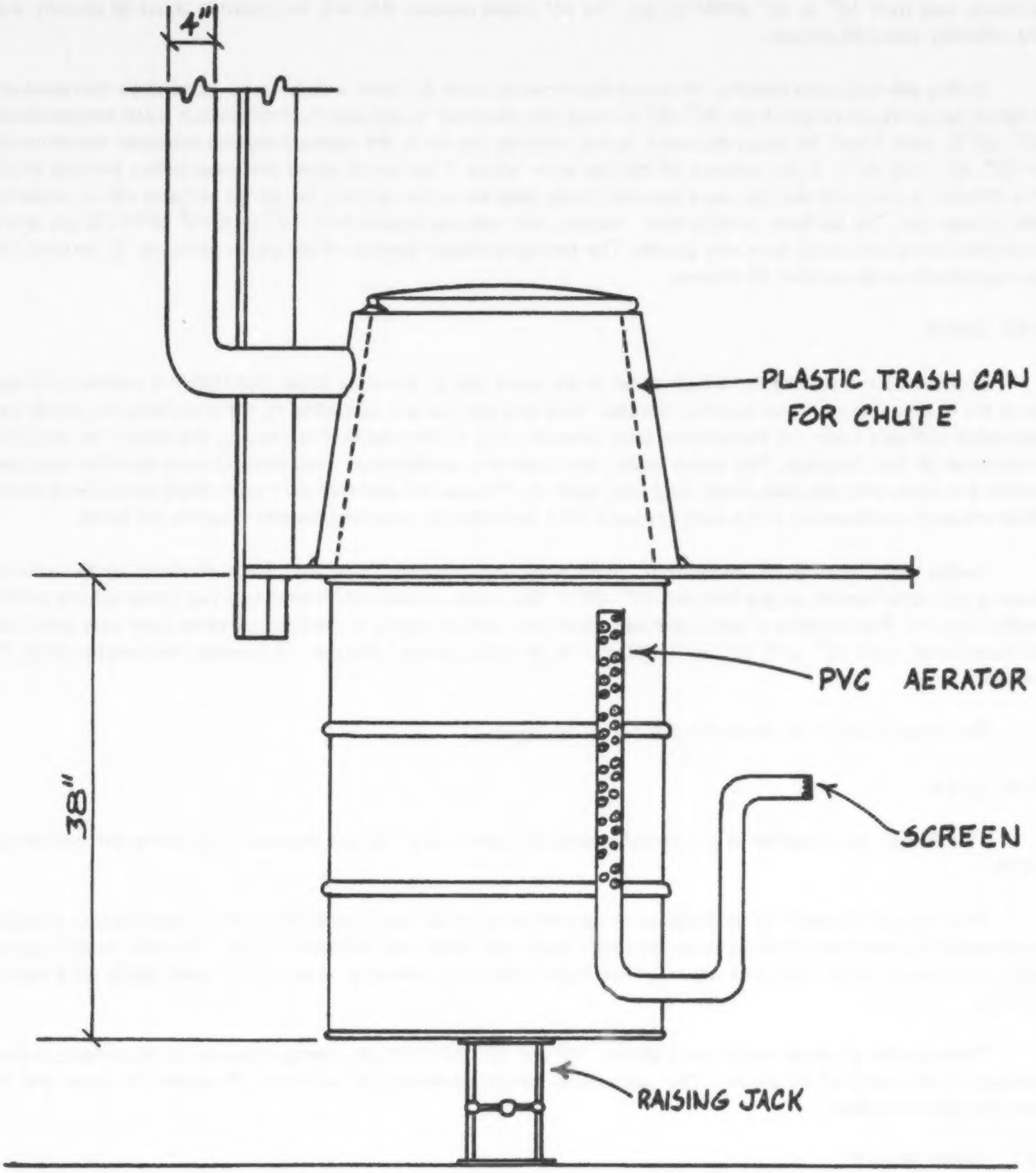

4"
PLASTIC TRASH CAN FOR CHUTE
PVC AERATOR
SCREEN
38"
RAISING JACK

FIGURE 7.60 DRUM PRIVY

Drums reportedly will fill and need replacement about every six to eight months of continuous use. The full drum is stored for one year during which time it is occasionally rolled to mix the contents. Exposure to sunlight is claimed to enhance decomposition. The finished product is then disposed of and the barrel can be reused. The interior of the barrel should be covered with a noncorrosive, water-tight coating.

### 7.61 Unit AA

This owner-built unit was unique because it contained two drums combined in series fashion which were partially burried with a mobile wooden enclosure on top. It was constructed on a 40-acre coastal lot in the spring of 1977. Observations began at about two years' use.

This double drum setup was observed for six months. Odors, flies, beetles, ants, and mice were noted present. Liquid periodically inundated the barrel. It was later determined that the bottom had rusted out. A forest fire incinerated this drum two months after it had been removed for storage.

The first four months' use of the new barrel was uneventful. During the next three months, red ants invaded the drum, groundwater inundated its contents, and anaerobic odors persisted. During the eight months, a mouse nested in toilet paper inside the barrel. At this point, the owners had built a flush toilet-subsurface disposal system and intended to move the privy to serve another dwelling. However, during the final six months of observation the privy house was apparently not used.

### 7.62 Unit BB

This owner-built unit consisted of a 55-gallon drum partially sunk in to a slope with a wooden enclosure resting on piles. It was constructed on a 40-acre coastal site in late 1976.

Observations began with a new barrel in service at eight months of system use. The owners added one pint of sawdust to this barrel after each use. Ammonia and $H_2S$ odors were periodically present. Flies were usually present but apparently did not concern the owners enough to screen vent openings and to improve the seal between the trash can chute and the top of the drum. The drum was removed, sealed, and was to sit for about six months before emptying.

The new in-use barrel contained a start-up layer of fir sawdust and ashes. One cup of ash was used after each use with this barrel. The drum was filled after eight months of use as study terminated.

Samples from the stored barrel left in a grassy field over an eight-month storage period varied from $10^{10}$ to $10^6$ MPN/100 gm coliform with a possible $10^2-10^4$ log reduction occurring over an eight month storage period. The moisture and volatile solids content, however, appeared unchanged over this time. Ambient air and solids temperatures remained between $10^\circ-15^\circ$C during this period. No other testing was conducted.

### 7.63 Unit CC

This owner-built privy on a 50-acre coastal site consisted of a 55-gallon drum resting on a jack over an open platform with a toilet chute. It was sealed to the drum by an inner tube which was attached with nails and caulking. The platform was roofed but had no walls. The wooden toilet lid was sealed with foam insulation and held in place with rocks. The unit was installed January 1977; observations began at about two years' use.

This unit was being used infrequently; the site occupants apparently resided elsewhere. Vector observations were no different for this unit than for a similar unit with an enclosed toilet room. One sample from a barrel stored for a year contained $10^2$ MPN/100 gm coliform, 70 percent moisture content, and 33 percent volatile solids. This drum was emptied in between site visits for on-site burial after about 18 months' storage. The in-use barrel was nearly full as the 18-month study ended.

### 7.64 Unit DD

This owner-built privy consisted of a 55-gallon drum which rested on a scissor jack and had a 4' x 7' wooden enclosed toilet room. The unit was built June 1978 and field observations began at eight months' use. The unit was noted to be very clean, well-screened, and all openings were sealed with weather stripping.

The in-use barrel filled at about the sixth month of observation. Barrels were changed shortly before site visit. Ammonia odors were present at new in-use barrel which had been put in service by using one cup of Douglas fir shavings after each use. An older drum which had been stored in a sunny spot for about one year was sampled, with laboratory results showing the coliform content to be $10^4$ MPN/100 gm, and the moisture and volatility to be 72 percent. Ambient temperatures ranged typically during the year from about 10°–30°C for this location.

Two additional stored drums were periodically tested at various storage times. During storage, the drums were rolled to mix the contents and the plastic vent was stuffed with steel wool to allow air circulation but to discourage fly entry.

One drum was stored for ten months and tested at one, seven, and ten months' storage. The appearance of the ten-month-old excrement was that of wet compost with intact appearing feces. Parasite eggs and cyst-like objects were present.

The other drum was stored five months and tested at zero, two, and five months' storage. The appearance of the five-month-old excrement was that of wet compost with intact appearing feces. Parasite eggs and larvae were present.

## 7.7 PIT PRIVIES

Four pit privies were observed but not sampled for analytical work during the observation period. The purpose of these observations was to note the rate of filling, the degree of owner/user acceptance, and the nature of added bulking materials.

Units EE through II were all infested with flies, mites, spiders, beetles and an occasional rodent. The fly population declined during winter months at all sites. None of the owner/users expressed concern about the vectors although one did use fly bait in a futile control effort. No particular efforts were made when constructing the pits to prevent or preclude vector access to the pit or the superstructure.

The rate of filling was difficult to determine since the pits varied in size and were dug in different soil types. The smallest pit measured 3.5 x 3.5 x 6 feet and accommodated a family of 4 users for about 3 years before it was necessary to dig a new pit. The frequency of usage also varied among the pit sites. Unit EE was used primarily in warm weather or when convenient since the family also had acquired an indoor box toilet, Unit R. Units FF, GG, and II were all noticeably wet throughout the study due to storm and/or surface runoff collecting in the pit. The site users tended to use whatever bulking agent was readily available. No kitchen- or garden-type wastes were added. Some lime and sawdust was used; however, all users were adding wood ash by the end of the study observations.

# SECTION 8
# DISCUSSION OF RESULTS
# DRY TOILET PERFORMANCE

## 8.1 CLIVUS MULTRUM AND SIMILARLY DESIGNED HOMEOWNER-BUILT UNITS

Of the six key determinants for the composting process identified in Section 4, four were measured directly. The following is a summary of field and laboratory data gained from observing seven Clivus Multrum and one homeowner-built unit of a similar design.

### Temperature

The field sanitarians were instructed to record temperature information about the center and edge of the compost pile as well as the air temperature adjacent to the storage chamber since many of the units were located in enclosed areas such as basement rooms under the home. Weather conditions on the day of sampling were also requested. Unfortunately, this information was rarely completed during the site visit. Since little variation appeared to be occurring between air and solids temperatures and because the sanitarians usually did record temperatures for the compost pile, the matter was simply not pursued. Staff accepted the fact that sampling toilet units was not an aesthetically pleasant task and that the samplers simply did not place a high priority on recording air temperatures. Most sites were located in coastal zones with mild climates. Temperatures varied between approximately 8°–18°C between November and April of the sampling period and between 19°–25°C during May through October. As noted in Table 8.10, the minimum temperature range necessary to achieve thermophilic bacterial decomposition, 25°–45°C, was noted within one unit. This only occurred during the first three months of usage. Then temperatures dropped to and remained within the minimum range for mesophilic decomposition. At least four units were at temperatures below that necessary for mesophilic bacteria to function. The temperature of the excrement pile did generally reflect changes in ambient weather conditions such as becoming cooler during the winter months and warmer in the summer. The barely perceptible biological decomposition exhibited by these units appears attributable to several interrelated factors, but primarily to excess liquid which was not evaporated. Since this step is a prerequisite to successful aerobic decomposition, all other factors became secondary in importance.

### Moisture

In general, the level of moisture within the composting chamber was greater than the 40–60 percent range which has been shown suitable for decomposition to proceed. Of 12 samples from 5 units, 9 samples from 4 units consistently had moisture levels outside of the ideal range. All but one of those values exceeded 60 percent. Since internal samples were taken and analyzed for units being subjected to one or more pathogen screens, some degree of randomness existed. Systems were chosen for sampling prior to the site observations and samplers did not intentionally seek out the wetter units. Liquid buildup problems occurred in all but one of the units as further evidence of the inability of these units to evaporate excess moisture.

### Bulking Agents

As discussed in an earlier section, the optimum moisture content for a particular system may vary with the type of bulking agent used. Table 8.11 shows the quantity and general type of bulking agent used within the seven large, sloped-floor biological toilets studied. This information came from two sources: monthly conversations with the user and recorded observations of the sanitarians. An important part of each sanitarian's responsibility was to clarify and validate user claims, for example, by visual observation of the unit's internal contents or by verbally probing for details about household practices. In most instances, the sanitarians were able to reasonably verify practices such as by seeing the actual bucket used by household B for addition of kitchen wastes and the scoop used for the addition of sawdust and by discussing practices of family members. Of course, some practices were impossible to quantify such as how frequently the lawn was mowed or the shrubbery trimmed and garden trimmings subsequently added to the unit. If a user claimed such practices and the sanitarian observed recognizable yard trimmings in the toilet vault, it was reasonable to conclude that the information was moderately accurate.

## TABLE 8.10 INTERNAL PROCESS DETERMINANTS

| SYSTEM | NUMBER OF DATA POINTS | NUMBER OF USERS | TEMPERATURE (°C) |  | pH |  | PERCENT MOISTURE |  | PERCENT VOLATILITY |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Range | Average | Range | Average | Range | Average | Range | Average |
| A | 3 | 3 | 16–26 | 20 | 6.0–7.7 | 7.1 | 71–80 | 75 | 44–85 | 67 |
| B | 1 | 3 | – | 19 | – | 8.2 | – | 62 | – | 84 |
| C | 3 | 1–4 | 8–19 | 13 | 7.3–8.2 | 7.9 | 31–70 | 50 | 9–53 | 27 |
| D | 2 | 4 | 17–21 | 19 | 5.6–7.6 | 6.6 | 58–59 | 59 | 38–76 | 57 |
| E | 3 | 2 | 14–20 | 19 | 6.5–7.0 | 6.8 | 71–78 | 74 | 75–83 | 77 |
| F | 6 | 2 | 11–18 | 17 | 6.4–8.3 | 7.2 | – | – | – | – |
| G | 4 | 5 | 16–22 | 20 | – | – | – | – | – | – |
| H | 2 | 2–4 | 12–18 | 15 | – | – | – | – | – | – |
| Summary Total | 24 | 1–5 | 8–26 | 18 | 5.6–8.3 | 7.3 | 31–80 | 66 | 9–85 | 52 |

## TABLE 8.11 DESCRIPTION AND QUANTITY OF BULKING AGENTS

| SYSTEM | KITCHEN WASTES | YARD TRIMMINGS | SAWDUST | PEAT MOSS | ASHES |
|---|---|---|---|---|---|
| A | Daily | – | – | – | Monthly |
| B | 2½–3 Gallons Weekly | – | ½–1 Pint Each Use | – | – |
| C | – | Frequent | – | – | – |
| D | Daily | Frequent | Bucketful Each 2–4 Days | – | – |
| F | Daily | – | – | 1 Pound Per Week | – |
| G | Daily | – | – | Bucketful Each Week | – |
| H | Daily | Monthly | Monthly | – | – |

As observers, the sanitarians and other field staff members made no attempt to influence the users' decisions about operating and maintenance practices. The users generally had manufacturer's printed instructions in the case of proprietary units and/or publications prepared by alternative technology advocates for reference material. In some locations, the vendor of proprietary devices could be consulted for information and advice. In no case did the field staff observe or have knowledge of a user receiving formal instruction in proper operation and maintenance techniques. It was assumed that the users of Clivus Multrum toilets had the manufacturer's operational guide as a minimum. This lists as a necessary additive kitchen garbage or some other material high in cellulose such as leaves, sawdust, shredded hay or straw. It does not discuss quantities although there is a discussion of how cellulose material absorbs liquid and "enhances aeration by giving the pile a loose structure."

As shown in Table 8.11, household kitchen wastes were routinely added to all except Unit C, to which garden trimmings were added per the manufacturer's suggestion. In general, most users did add the recommended sawdust. Apart from moisture control, bulking agents contribute to maintaining the structural integrity of the composting pile and to supplementing available carbon and nitrogen content. The structural integrity of the pile relates to its ability to maintain aerobic conditions throughout the pile. With a granular bulking agent such as sawdust, aerobic conditions are difficult to maintain when moisture levels approach or exceed 70 percent. Seven of 12 samples had moisture levels greater than 70 percent, and those units subsequently were shown to exhibit other symptoms of anaerobic conditions such as the presence of sulfide-type odors and rapidly declining temperatures.

In addition to choosing an inappropriate bulking agent, users grossly underestimated the quantity required for the Clivus unit. Another function of bulking agents (with these large units only) can be to supply adequate energy resources or carbon for continuing microbiological growth. Human excrement contains large amounts of nitrogen and is lacking in a source of combustible carbon. The optimum carbon/nitrogen balance for composting is about 25 or 30 to 1. This ratio can be achieved by providing an adequate outside source of carbon, supplied by adding bulking agents. As discussed in Section 4, the limiting nutrient, carbon, is usually supplied by adding bulking agents. System B was noted by the sanitarian to have the greatest quantity of added material. Using the information in Table 8.10, excrement volume information from Gotaas and Van der Ryn, and assuming that all three occupants of household B use only toilet B for one week, a rough estimate of the quantity of toilet wastes produced can be calculated as follows:

$$\frac{2.5\ \text{lbs/input/person} \times 3\ \text{people} \times 7\ \text{days/week}}{8.34\ \text{lbs/gallon}} \cong 6.3\ \text{gallons/week}$$

The quantity of bulking agents added during this hypothetical week can be calculated using information from Table 8.11. This assumes 2.75 gallons of kitchen wastes are added during the week and that each person visits the toilet 2 to 4 times and adds a quart of sawdust per day. The quantity of bulking agents added is, therefore, calculated as follows:

$$\frac{2.75\ \text{gallons}}{7.48\ \text{gallon/cubic foot}} + \frac{1\ \text{quart/day} \times 3\ \text{people} \times 7\ \text{days/week}}{4\ \text{quart/gallon} \times 7.48\ \text{gallon/cubic foot}} \cong 1.1\ \text{cubic foot/week}$$

Thus for Unit B, the ratio of 6.3 gallons of toilet wastes to 1.1 cubic feet of bulking agent is added to this system each week. As previously reported, the greatest ratio known to successfully compost is 1.5 gallons of wastes per 1 cubic foot of bulking agent. Based upon the accuracy of these two calculations, this unit appears to be about 75 percent short of the quantity of bulking agent necessary for composting to occur if no evaporation were to occur. Of course, in reality this shortfall may not exist if adequate evaporation is occurring and pores are open for free passage of air. Partially successful evaporation can result in the formation of anaerobic pockets.

This discussion is appropriate for very large units such as the Clivus only, where wastes may be absorbed by the bulking agents. Other biological toilets utilize bulking agents in smaller quantities for the purpose of keeping the porosity of the pile adequate for free passage of air to insure aerobic conditions only.

The oxygen content of the pile was not directly measured. Theoretically, the oxygen content relates primarily to percent moisture and mixing and to a small degree the carbon/nitrogen ratio. The manufacturer suggests that a draft or an air flow through the system maintained by natural convection or with the assistance of a small fan ensures that the process is essentially aerobic. This assumes that the structural morphology of the pile is loose enough to accommodate this type of natural or passive mechanical aeration. However, the results of analytical testing on Table 8.10 show that the internal contents of these units contain too much moisture and not enough added material to allow the pile to maintain pore space for air. All units had vent fans but all units were also soggy, compact, and appeared anaerobic (e.g., ammonia and sulfide odors). Only one user mechanically turned or mixed the pile for added aeration on a regular frequent basis. Unfortunately, the effect of weekly mixing could not be ascertained because the unit was only observed for a short time.

The internal process is theoretically dependent on wastes from the toilet chute moving by gravity to and mixing with wastes from the kitchen refuse port. This theoretical physical mixing in combination with mechanical aeration allegedly keeps the pile aerobic. One user raked the surface, while two users mechanically mixed the internal contents but at differing frequencies. The ability to judge whether or not mechanical mixing occurred was therefore obscured in these units. However, observations about the remaining five units demonstrate that little or no natural mixing occurred; two discrete piles were commonly noted as well as identifiable blocks or masses of solids indiscriminantly "avalanching" into the final compartment. Frequent mechanical mixing may be a necessity to maintain aerobic conditions in these units.

As one might expect, only a slow rate of decomposition can take place under conditions previously described. Table 8.12 shows the results of laboratory analyses of the end product from the eight Clivus-type units. Each data point represents a composite sample of the end product taken by the sanitarian whenever solids were observed in the humus storage chamber during their monthly site visits.

TABLE 8.12 CLIVUS MULTRUM: END PRODUCT CONDITION

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| A | 1 | – | $10^6$ | 5.9 | – | 78 | – | 85 | – |
| B | 6 | $10^5-10^7$ | $10^6$ | 6.9–7.5 | 7.1 | 36–72 | 53 | 11–82 | 53 |
| C | 4 | $10^4{-}{>}10^9$ | $>10^6$ | 5.0–7.5 | 6.4 | 28–44 | 37 | 12–15 | 14 |
| D | 10 | $10^4-10^8$ | $10^6$ | 5.6–7.9 | 6.4 | 19–66 | 51 | 42–85 | 58 |
| E | 9 | $10^3-10^8$ | $10^5$ | 4.4–5.5 | 5.1 | 27–85 | 49 | 3–40 | 13 |
| F | 9 | $10^2-10^8$ | $10^3$ | 3.6–5.7 | 4.7 | 12–75 | 42 | 34–96 | 70 |
| G | 0 | New Unit, No Product | | | | | | | |
| H | 0 | New Unit, No Product | | | | | | | |
| Summary Total | 39 | $10^2{-}{>}10^9$ | $10^6$ | 3.6–7.9 | 5.9 | 12–85 | 52 | 3–96 | 49 |

The principal objectives of composting have apparently not been accomplished. With an average of $10^6$ MPN coliform organisms per 100 grams of solids and a variability of $10^2 - \geqslant 10^9$, there is some question that pathogenic organisms could survive if present. It is possible from the wide range of values shown on Table 8.12 that the length of storage of toilet wastes provided by these units may not reduce the inherent risks due to microbiological hazards, but total coliform measurements without supplemental evidence are not specific enough to quantify the problem. The positive virus, bacteria, and parasite tests are specific evidence of potential pathogenic hazards.

It is difficult to assess how well the degradable organic matter has been stabilized from apparent changes in volatile content as reported in Tables 8.10 and 8.12 because of the problem of obtaining representative samples. While Unit A shows an apparent increase in volatility, Unit D suggests no change has occurred. Units B, C, and E appear to have widely differing levels of reduction. Using the method developed by Schulze,[88] the reduction of organic matter is:

$$O_R = \frac{(AD-AR)\,10^4}{AD(100-AR)}$$

where $O_R$ = reduction in organic matter, %

AD = ash content of decomposed product, %

AR = ash content of raw material, %

From this method the reduction of organic matter from units B, C, and E average 79 percent, 48 percent, 96 percent, respectively, without considering sampling error and bulking agent effects. The Norwegian criterion[84] of 30 percent decomposition would apparently have been met by these three units, but other testing criteria would not be met. The 96 percent reduction reported for Unit E must be interpreted in view of the fact that the storage compartment was submerged in liquid throughout the study. Samples were taken by pumping the liquid out to expose solid material, such that what may have been sampled is the insoluble soil fraction of the bedding material. Although of limited value, the data from Unit E provide an excellent example of how well-intentioned management can still result in a failing system.

The end product was neither uniform nor fairly dry as evidenced by the random movements of portions of the piles in the composting chamber and by fact that there was little change in moisture content.

The toilet itself appears sanitary since the storage chamber functioned adequately to contain the waste products and the physical appearance of the bathroom was aesthetically acceptable to the users. However, since the product must be disposed of, its risks cannot be overlooked. The process was definitely not free from vectors; a range of organisms was observed in or about the unit. The process was not free from odors; as anaerobic conditions developed, so did the odors.

Nonetheless, it appears that pH changes to the acid range did occur and that the decomposition process was almost imperceptibly slow due to inadequate evaporation and mixing.

## 8.2 LARGE, SLOPED-FLOOR PROPRIETARY UNIT

The following is a summary of field and laboratory data gained from observing three Toa Throne units. The Toa Throne appears to function similarly to the Clivus units. Temperatures reached marginal mesophilic ranges; the chambers retained too much moisture; and the bulking agents used were usually of inappropriate quality and inadequate quantity. With only one waste chute, both excrement and bulking agent are added to the same spot. However, the Toa Throne apparently has a need similar to the Clivus for mechanical mixing. The combined wastes neither move down the slant nor attain higher temperatures. Large quantities of liquids also built up in all three units when use included urination. This liquid either overflowed onto the area adjacent to the storage vault, was bailed out, or was plumbed to the grey water system for subsurface disposal. The last alternative appears preferable in view of laboratory findings from analyzing this liquid buildup (see Section 8.82 for further discussion).

**TABLE 8.20 TOA THRONE: INTERNAL PROCESS DETERMINANTS**

| SYSTEM | NUMBER OF DATA POINTS | NUMBER OF USERS | TEMPERATURE (°C) | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | Average | Range | Average | Range | Average | Range | Average |
| I | 6 | 2 | 14–26 | 20 | 5.7–7.6 | 6.5 | 36–71 | 59 | 54–71 | 62 |
| J | 7 | 2 | 10–22 | 15 | – | 8.3 | – | – | – | – |
| K | 7 uses/day | 6–8 | 12–26 | 20 | 5.5–8.6 | 7.0 | 72–81 | 76 | 76–85 | 81 |
| Summary Total | 20 | ~2 | 10–26 | 18 | 5.5–8.6 | 7.3 | 36–81 | 68 | 54–85 | 72 |

The users of this type of unit were also uninformed about the purpose and quantity requirements of bulking agents. As the units filled, users uniformly stopped adding plant material and/or kitchen wastes because they felt it either saved space for more excrement or that it would eliminate problems with flying insects. What then happened to two of the units is similar. The walls of the unit bulged and the air baffles collapsed under the weight of the pile. The third unit was showing signs of the same strain when it was abandoned in favor of a flush toilet connected to a new septic tank leach field.

Table 8.21 shows the results of laboratory analyses of end product from two Toa Throne units. As described in Section 6.2, Unit I was observed for a 12-month period of continuous usage with no end product produced. Both Units I and K failed structurally during the course of study observations. Units J and K were abandoned in favor of a flush toilet connected to a subsurface leach field. Unit I was abandoned and another type of dry toilet was installed in the home.

**TABLE 8.21 TOA THRONE: END PRODUCT CONDITION**

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| I | – | System Failure | | | | | | | |
| J | 6 | $10^3-10^7$ | $10^5$ | 5.6–7.3 | 6.4 | 2–78 | 48 | 10–66 | 45 |
| K | 7 | $10^8-10^{10}$ | $10^9$ | 6.8–7.7 | 7.3 | 72–83 | 79 | 62–85 | 69 |
| Summary Total | 13 | $10^3-10^{10}$ | $10^7$ | 5.6–7.7 | 6.9 | 2–83 | 64 | 10–85 | 57 |

The system might function, assuming a continuous process is viable, if the structural design problems are corrected and the contents of the vault contain appropriate bulking agents and are frequently mechanically turned. The response of Unit K appears to support these suggestions since elevated temperatures and acid pH levels were registered shortly after the standing liquid was removed and more absorbents were mechanically mixed into the pile. The organic matter reduction measured for that unit was 90 percent, but no other Norwegian criteria were met.

The range and variability of end product conditions suggests the principal objectives of composting have not been met. The end product is not free from pathogens, vectors, or liquid. It is clearly advisable to further compost the end product at least an additional six months as suggested by the manufacturer.

## 8.3 VAULT PRIVY

As described in Section 6.3, the vault system can function with or without oxygen. The five units monitored appeared to be operated so that the in-use side was aerobic and the resting side was to be anaerobic. The in-use side of two units was sampled four times. Assessment of in-use processes determinants will not be made with such limited data. The resting side, however, was monitored and the following discusses laboratory findings from nine "aging" sequences.

The results of testing samples from the aging compartment of Unit L are shown in Table 8.30. Although the owner reportedly turned the in-use pile monthly, the aging pile was only disturbed initially when the solids were placed into the storage vault. No additional bulking materials were added at the time of the move. No changes were apparent during the four month sequence possibly because of limited nutrients. In addition, the system was not kept free from additional liquid. The moisture content may be bordering conditions unfavorable for aerobic and/or anaerobic decomposition. If the system were intentionally anaerobic, no attempt was made to seal vents and openings nor to fill the head space with bulking agent. In short, the process appears to have achieved the acid formation stage prior to being moved into the storage vault but biological decomposition ceased when conditions were either limiting or inhibitory. The end product from this unit may require further treatment prior to disposal. If rapid aerobic processes are desired, intensive mechanical mixing is mandatory as well as the addition of adequate quantities of combustible bulking agents. Proper siting of the unit is also a necessity to preclude groundwater infiltration and/or storm runoff from entering the vaults.

**TABLE 8.30 UNIT L AGING SEQUENCE**

| AGING CYCLE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 0 | 12 | 21 | 5.4 | $10^7$ | 62 | 87 |
| 1 | 11 | 18 | 5.6 | $10^7$ | 73 | 81 |
| 2 | 12 | 18 | 5.6 | $10^7$ | 64 | 71 |
| 3 | 8 | 10 | 5.2 | $10^6$ | 69 | 75 |
| 4 | 4 | 9 | 5.6 | $10^6$ | 67 | 83 |

Table 8.31 shows the results of testing the aging side of Unit M. Neither aging nor in-use sides are turned. Little if any biological decomposition is likely happening here since the system is clearly too cold and too wet. A parasite screen at two months shows larval forms, and a bacteria screen isolated *Proteus* and *Citrobacter* forms. This unit is also plagued with liquid buildup and the presences of many vectors. Use continued until the vaults were entirely filled, then both vaults were emptied for disposal without benefit of intentional composting. There is clearly a need for user education to take advantage of biological decomposition and to reduce inherent health risks during handling and disposal operations.

**TABLE 8.31 UNIT M AGING SEQUENCE**

| STORAGE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 1 | 7 | 8 | 6.5 | $\geqslant 10^9$ | 76 | 83 |
| 2 | 8 | 5 | 6.9 | $10^9$ | 73 | 77 |
| 3 | 14 | 14 | 7.5 | $10^9$ | 73 | 80 |
| 5 | 14 | 12 | 7.7 | $10^7$ | 53 | 79 |

Table 8.32 shows the results of two aging sequences monitored at Unit N. As was the case with Units L and M, the only discernible change is a natural change due to seasonal fluctuations in ambient air temperature. Siting is also a problem here since the unit is subject to storm water runoff and groundwater infiltration. The storage vaults are obviously not watertight and trapped water cannot easily exit because the bottom liquid drains become plugged. The trapped liquid appears to inhibit biological decomposition and to attract vectors to the unit.

TABLE 8.32 UNIT N AGING SEQUENCE

| STORAGE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 0 | 36 | 29 | 8.9 | – | – | – |
| 3 | 9 | 25 | 8.3 | $10^6$ | 67 | 61 |
| 4 | 13 | 24 | 8.2 | $10^7$ | 53 | 28 |
| 5 | 7 | 22 | 7.8 | $10^7$ | 64 | 51 |
| | | | | | | |
| 0 | 2 | 16 | 7.4 | $\geqslant 10^9$ | 72 | 67 |
| 1 | −4 | 13 | 7.2 | $10^8$ | 37 | 18 |
| 2 | 3 | 9 | 7.8 | $10^9$ | 67 | 25 |
| 3 | 7 | 11 | 7.3 | $10^8$ | 63 | 71 |
| 5 | 13 | 14 | 7.9 | $10^8$ | 67 | 82 |

Higher temperatures in the first sequence could be related to seasonal factors and to the quality of the bulking agent. Redwood sawdust was the additive when that side was in use. Additional quantities of wood ashes were mechanically mixed into the pile at the start of the aging sequence. This is reflected by the alkaline pH and by the higher initial temperature. This sequence was also run June through October. Lower ambient temperatures reported for samplings at the third through fifth months reflect the sanitarian's decision to avoid working during the hotter days by visiting the site early in the morning hours at approximately 0630. The weather is warmer and dryer than the wet weather sequence November through April of the second recorded process. The aging side was probably mechanically turned on a more frequent regular basis than when wet weather made access to the unit more difficult and made the contents wetter and less easily turned.

The contents of both aging sequences were further composted with garden refuse before final disposal.

The aging sequences shown for Unit O on Table 8.33 are the longest observed in the study. Several concepts were monitored and the resultant information is discussed in the following.

TABLE 8.33 UNIT O AGING SEQUENCE

| STORAGE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 5 | 16 | 16 | – | – | – | – |
| 7 | 20 | 14 | 5.0 | – | – | – |
| 8 | 16 | 18 | 6.5 | – | – | – |
| 9 | 22 | 18 | – | – | – | – |
| 10 | 26 | 20 | 5.0 | $10^3$ | 30 | 82 |
| 11 | 23 | 18 | 5.5 | $10^3$ | 29 | 70 |
| 12 | 25 | 18 | 5.5 | $10^3$ | – | – |
| | | | | | | |
| 0 | 25 | 19 | 5.3 | $10^9$ | 36 | 68 |
| 1 | 13 | 12 | 5.5 | – | – | – |
| 2 | 11 | 8 | 6.2 | – | – | – |
| 3 | 13 | 8 | 5.4 | $10^5$ | 53 | 68 |
| 4 | 14 | 11 | 5.7 | $10^5$ | 74 | 23 |
| 6 | 16 | 11 | 6.3 | $10^7$ | 62 | 90 |
| 7 | 18 | 13 | 5.2 | $10^7$ | 61 | 73 |
| 8 | 26 | 16 | 4.8 | $10^5$ | 55 | 85 |

Pathogen survival has been a serious concern to health officials. A confirmed case of Salmonella was diagnosed of a Unit O user about five months before study observations began. Pile temperatures and pH were monitored, generally showing little change during the last 7 months of a 12-month storage cycle. Pathogen screens during the last few months failed to detect *Salmonella.* However, with coliform at $10^3$ MPN, bacteria screens isolated *Enterobacter, Citrobacter,* and *Yersinia. Yersinia* is recognized as an etiologic agent,[49] human infections may result in acute gastrointestinal illness, septicemia, meningitis, and other forms of illness. The agents of disease apparently remain viable and detectable with a years' storage time, and with greatly reduced levels of indicator organisms present.

The second aging sequence began with a new isolation of *Salmonella*; the individual with the earlier illness is now apparently an asymptomatic carrier. Coliform levels were at $10^9$ MPN, *Citrobacter* and *Proteus* were also isolated. Similar testing at 3, 4, 7, and 8 months' storage failed to isolate *Salmonella*. However, *Klebsiella* and *Serratia* are repeatedly isolated even though coliform is reduced 4 logs to $10^5$ MPN. The inability to detect *Salmonella* forms beyond 3 months' storage time is consistent with survival studies of this bacterium conducted by Yitzhaki,[50] in which the organisms decreased continuously in wet sand until they were undetectable after 50 days. Although a certain amount of controversy exists about which species of *Klebsiella* and *Serratia* are pathogenic to humans, there is little question that *K. pneumoniae* and *S. marcescens* which were isolated are pathogens.[51] In a similar manner, *Enterobacter, Yersinia,* and *Citrobacter* were isolated and each contain one or more recognized human pathogenic form.

Low levels of coliform bacteria may provide assurances that other pathogenic forms are not present within a water or wastewater environment. They appear to afford the same protection for solids of fecal origin, especially where the organic content is dominant.

Although both batches of aging solids received equivalent attention, the pile temperatures were greater during dry, warm weather than during the wetter, colder months similar to Unit N. The owners buried the year-old solids in an orchard area.

As with Units L, M, and N, data for Unit O suggests that little discernible physical change is occurring during storage.

Table 8.34 shows data from three short aging cycles monitored at Unit P. These cycles appear to have the same tendencies as the previous four vault systems, that is declining temperatures during wetter colder months and no apparent change in moisture or volatility. Where these cycles differ is with pH change and with coliform reduction.

**TABLE 8.34 UNIT P AGING SEQUENCE**

| STORAGE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 0 | 37 | 32 | 7.0 | – | – | – |
| 1 | 21 | 17 | – | – | – | – |
| 2 | 24 | 22 | 5.0 | $10^6$ | 29 | 86 |
| 3 | 23 | 20 | 6.4 | $10^2$ | 40 | 66 |
| 0 | 23 | 23 | 6.2 | – | – | – |
| 1 | 31 | 20 | 5.2 | $10^7$ | 21 | 67 |
| 2 | 22 | 14 | 4.8 | $10^5$ | 20 | 71 |
| 3 | 20 | 12 | 4.4 | $10^3$ | 57 | 86 |
| 4 | 26 | 10 | 5.4 | $10^3$ | 62 | 32 |
| 0 | 26 | 17 | 8.6 | – | – | – |
| 1 | 13 | 11 | 6.2 | $10^9$ | 39 | 90 |
| 3 | 24 | 18 | 6.3 | $10^9$ | 60 | 93 |
| 4 | 19 | 13 | 4.3 | $10^6$ | 64 | 77 |
| 5 | 17 | 16 | 4.3 | $10^5$ | 63 | 89 |

The pH consistently declined into the acid range. This may be notable because system usage was primarily for defecation, bulking agents included straw, kitchen vegetable wastes, and sawdust. The system was drier than the other systems; less liquid was put into the system in the form of urine and little if any infiltrated from storm runoff or rising groundwater levels. The siting and interior asphaltic coatings may be responsible. Frequent manual mixing apparently kept the pile organisms functioning during the initial phase of storage. It does show that the process stops after about two to three months, possibly due to limiting nutrients. Bulking material was not added after storage began.

Bacteria screens were run on three samples that had coliform levels of $10^9$, $10^6$, and $10^3$ MPN. *Citrobacter, Klebsiella,* and *Yersinia* forms were isolated at the lowest MPN level, which suggests that an incomplete composting operation conducted at temperatures below mesophilic ranges does not provide reliable pathogen removal. In addition parasite screen findings of live larvae at both $10^9$ and $10^3$ MPN coliform levels further supports the contention that lower temperature decomposition does not fulfill the principal objectives of composting.

## 8.4 BOX-LIKE TOILET WITH TOPPING BAR

Of the six key process determinants, only temperature was consistently measured for the four Mullbank units. The results of that limited monitoring are shown in Table 8.40. Twenty-three of 38 data points were of temperatures less than 25°C, which is the minimum temperature for mesophilic decomposition. None of the temperatures were above 40°C, 29 of the readings were below 30°C. This is significant since manufacturer's literature claims that the units' heating element will heat the pile to 50°C. In addition, three of the units exhibited anaerobic odors while at temperatures between 27°–38°C. The addition of small amounts of heat may not benefit the composting processes when other process determinants are unfavorable. Although limited, seven data points for moisture content suggest that the systems are too wet for biological processes to proceed. The ammonia and sulfide odors observed coupled with the absence of a convenient mechanism for mixing the toilet contents suggests that the system may not be aerobic.

TABLE 8.40 MULLBANK: INTERNAL PROCESS DETERMINANTS

| SYSTEM | NUMBER OF DATA POINTS | NUMBER OF USERS | TEMPERATURE (°C) | | pH | | PERCENT MOiSTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | Average | Range | Average | Range | Average | Range | Average |
| Q | 8 | 1–2 | 14–27 | 20 | 5.6–7.8 | 6.5 | – | 75 | – | 76 |
| R | 9 | 4 | 22–40 | 31 | 7.8–8.8 | 8.3 | 72–74 | 73 | 80–82 | 81 |
| S | 11 | 3–4 | 19–35 | 24 | – | – | – | – | – | – |
| T | 10 | 1 | 19–33 | 26 | – | 8.1 | – | 62 | – | 11 |
| Summary Total | 38 | 1–4 | 14–40 | 25 | 5.6–8.8 | 7.3 | – | 75 | – | 76 |

The only mechanism available within the toilet vault is a topping bar that breaks easily and that moves from side to side, eliminating the top of the cone from the excrement pile. Although the manufacturer describes a monthly maintenance schedule for manual redistribution of wastes throughout the waste chamber and for periodic additions of bulking materials, none of the users reported doing this. The users of two units specifically objected to physical manipulation of the wastes; the user of the third unit was at home about three days per week. The users of the fourth unit felt that the presence of an indoor toilet was an advantage over their outdoor pit privy; however, the inability of this family to maintain the recommended schedule also suggests that the techniques described may be unacceptable to system users. Since none of the users carried out the recommended maintenance schedule, there is no way to evaluate whether the system would have performed differently with the scheduled maintenance. However, this unit performed similarly in Norwegian studies and is no longer produced.[89]

Table 8.41 shows the results of analyzing solids from the collection tray of four Mullbank units. While Units Q, R, and S show similar results, the data for Unit T shows fewer coliform surviving, a lower volatility, and generally a dry end product. This unit was used every other day by one individual who maintained the unit more frequently than the other unit owners. The volume of wastes was quite small and holding time of the wastes in the toilet was long. The wastes remained in the toilet for eight months before the manufacturer's scraper was used to bring down a tray full of dry solids. Users of the other three units failed to follow this recommended procedure. Observers had to scrape sample material into the collection tray. It did not fall through of its own accord and the scraping technique was likewise unacceptable to users.

TABLE 8.41 MULLBANK: END PRODUCT CONDITION

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| Q | 6 | $10^4-10^9$ | $10^6$ | 6.6–8.9 | 7.8 | 60–76 | 69 | 33–68 | 54 |
| R | 7 | $10^2-10^6$ | $10^4$ | 6.8–8.4 | 7.9 | 23–66 | 51 | 18–83 | 33 |
| S | 7 | $10^3-10^7$ | $10^4$ | 6.0–8.4 | 7.4 | 7–68 | 47 | 33–61 | 42 |
| T | 7 | $<10^2-10^7$ | $\leq 10^3$ | 5.1–7.8 | 6.6 | 2–78 | 19 | 11–41 | 24 |
| Summary Total | 28 | $<10^2-10^9$ | $\leq 10^4$ | 5.1–8.9 | 7.4 | 2–78 | 47 | 11–83 | 38 |

The overall condition of the end product is similar to ranges for moisture and volatility observed for the larger proprietary units. The pH value, however, remains in the normal range for excrement. The only apparent effect of the added heat is to hasten drying when usage is reduced or stops. It does not appear to alleviate large volumes of collected urine that predominate the collection tray under the conditions of use in all toilets except Unit T. It certainly does not discourage a variety of vectors from being attracted to the unit. Of six samples screened for parasites, five contained live larvae and two had cyst-like structures. One contained dead larval forms.

The flying insects were the greatest source of aggravation for the users. Odors, liquid buildup, and an easily broken topping are also of concern.

## 8.5 BOX-LIKE TOILET WITH ROTOR

Table 8.51 is a summary of field and laboratory data gained from observing four Bioloo units. The data for the Bioloo units are similar to findings for the Mullbank; the contents are generally too wet to decompose biologically. Of 28 temperature readings, 21 are within the minimum range for thermophilic decomposition; however, conditions apparently are not favorable for those microbiological organisms. Very little bulking material was used, therefore the combustible carbon content was likely limited. The alkaline pH values noted for Units V and W were probably due to the addition of fireplace ashes. All four units exhibited anaerobic odors under normal use which became noticeably worse if there were additional users. The internal rotor apparently was not adequate to keep aerobic conditions. All users claimed to regularly crank the rotor with each use. Two of the units experienced problems with broken rotor handles when the pile became "too stiff or dry." The internal conditions necessary for the handle to work are not necessarily consistent with those favorable for aerobic decomposition.

### TABLE 8.51 BIOLOO: INTERNAL PROCESS DETERMINANTS

| SYSTEM | NUMBER OF DATA POINTS | NUMBER OF USERS | TEMPERATURE (°C) | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | Average | Range | Average | Range | Average | Range | Average |
| U | 10 | 4 | 21–44 | 35 | 7.3–8.3 | 7.8 | 71–78 | 75 | 67–79 | 74 |
| V | 10 | 1 | 23–48 | 32 | 8.6–9.4 | 9.1 | 78–79 | 79 | 67–69 | 69 |
| W | 8 | 1 | 15–46 | 31 | 9.2–10.0 | 9.6 | – | – | – | – |
| X | 2 | 3 | – | – | 8.1–8.2 | 8.2 | 62–68 | 65 | 61–65 | 63 |
| Summary Total | 30 | 1–4 | 15–48 | 33 | 7.3–10.0 | 8.7 | 62–79 | 73 | 61–79 | 69 |

The 11 data points reported in Table 8.52 are from samples which were subjected to the "pasteurization" heat treatment cycle. It is recommended that solids be subjected to the entire 6-hour cycle since Unit X interrupted the cycle after 1.5 hours, resulting in higher coliform levels in the product. Samples from Units U and W were reportedly cycled at least six hours and Unit V for 4 to 6 hours. There appear to be three discernible effects of this heat treatment. The obvious one is the reduction of coliform indicator organisms. The exact level cannot be determined since the test protocol did not allow for determinations below $10^2$ MPN measured between 50°–63°C, two samples screened for parasites contained only nonviable larvae. Both samples were noted to look like wet, muddy solids. There is no way to assess whether the unit can achieve temperatures in the intended range of 70°C under other conditions such as drier starting solids containing bulking agents with heat retaining properties. Furthermore, the reliability of such a cycle would still require laboratory confirmation.

### TABLE 8.52 BIOLOO: END PRODUCT CONDITION

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM | | pH | | PERCENT MOISTURE | | PERCENT VOLATILITY | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| U | 3 | – | $< 10^2$ | 7.9–8.3 | 8.1 | 78–84 | 82 | 70–79 | 75 |
| V | 3 | $< 10^2–10^4$ | $< 10^3$ | 7.4–8.6 | 7.9 | 81–85 | 83 | 62–80 | 69 |
| W | 4 | $< 10^2–10^4$ | $< 10^3$ | 7.4–8.1 | 7.7 | 78–80 | 79 | 61–70 | 67 |
| X | 1 | – | $10^5$ | – | 8.6 | – | 70 | – | 68 |
| Summary Total | 11 | $< 10^2–10^5$ | $< 10^3$ | 7.4–8.6 | 8.1 | 70–85 | 79 | 61–80 | 70 |

The second effect of the heat treatment cycle was to produce large quantities of odors which were noticeable a block away from the homes in the case of two nearby residents who heat-cycled solids at the same time.

The third effect is a reconfirmation of observations made about added heat with the Mullbank unit If conditions are inappropriate for biological decomposition to proceed, for example, excessive lack of oxygen such as with the Bioloo units, biological decomposition will not likely start simply because the solids were subjected to a heat source. The ranges shown for pH, moisture, and volatility suggest little, if any, decomposition has occurred.

Energy consumption was not directly measured during the course of study observations. The true cost of this system should also include that which is necessary to maintain warm temperatures in the bathroom. System owners with two or more users found this necessary to avert collecting standing liquid within the unit and the collection tray.

## 8.6 DRUM PRIVY

The four drum privy units all were characterized by anaerobic odors, a diverse collection of vectors, and surface and/or storm water intrusion.

Ammonia and/or sulfide odors were present at nearly every site visit of all units. The visits where no odors were detectable generally had ash additions which elevated the pH of the solids to 9 to 10, or the unit had been unused for days prior to the site visit.

Unit DD was built and maintained in a superior fashion as compared to Units AA, BB, and CC. The enclosed toilet room was well screened, and openings sealed with weather stripping. The toilet seat and throne connections were sealed with gasketing material. Signs in the privy room discourage using the unit for urination, vent openings were capped to preclude rainwater from entering the barrel. However, the diversity of vectors isolated from the in-use barrel shows no apparent difference from the other drum units. Flies, spiders, mites, and live larvae were attracted to and collected from the in-use barrel of Unit DD throughout the study irrespective of good housekeeping and good preventive techniques. Other problems noted during system use were with an uncoated drum bottom rusting out and with the weight of the full barrel. A full barrel can weigh nearly 300 pounds and pose difficulty when removing for storage. Barrel changes required several strong individuals and a great deal of physical effort.

The suggested technique for finishing the drum process involves storing the full drum for a year in a place where exposure to sunlight will hasten decomposition of the collected wastes. Drums were generally stored in a sunny spot but not for recommended time. Three out of five stored drums were inadvertently destroyed in a forest fire while the others were emptied when in-use drums filled and an empty replacement was necessary. One owner buried aged excrement on site near fruit trees. The other owner had not decided on the method of ultimate disposal. Samples were taken periodically from available barrels in storage to ascertain the nature of changes occurring to the stored solids. Table 8.61 shows information for Unit AA over a 10-month storage period. No additional testing was conducted for this unit or for Unit BB shown on Table 8.62.

TABLE 8.61 UNIT AA AGING SEQUENCE

| AGING CYCLE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 1 | 21 | 19 | 8.4 | $10^6$ | 51 | 52 |
| 5 | 11 | 10 | 7.8 | $10^9$ | 64 | 61 |
| 7 | 15 | 10 | 7.4 | $10^9$ | 75 | 68 |
| 10 | 22 | 20 | 7.9 | $10^8$ | 68 | 55 |

TABLE 8.62 UNIT BB AGING SEQUENCE

| AGING CYCLE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 1 | 14 | – | 8.7 | $10^{10}$ | 36 | 77 |
| 3 | 9 | 7 | 7.7 | $10^{9}$ | 73 | 77 |
| 5 | 15 | 14 | 7.1 | $10^{7}$ | 70 | 85 |
| 8 | 20 | 20 | 6.9 | $10^{6}$ | 70 | 83 |

System usage for Unit CC was too low for frequent site visits. Only one stored drum was accessible briefly for sampling. The results of laboratory work on this sample of year-old solids and accumulated liquid show coliform of both liquid and solid samples at $10^2$ MPN. The accumulated liquid contained high amounts of dissolved solids (48,000 mg/l) and nitrogen (1,800 mg/l).

The appearance of both the five- and ten-month-old samples from Unit DD was that of wet compost with intact appearing feces. Eggs, larvae, and cyst-like objects survived the storage process.

Drums of stored excrement do not appear to be biologically decomposing at a perceptible rate, as evidenced from data shown on Tables 8.61, 8.62, and 8.63. Parasite forms and coliform indicator organisms survive quite well. Apparently the effect of being at ambient temperatures for long periods of time serves to preserve more than decompose excrement. Temperature increases and decreases appear to follow seasonal conditions as noted within other generic unit types. Storage time and ambient conditions of a coastal environment did not provide reliable pathogen destruction or discernible organic decomposition. The stored drums served to attract and harbor many vectors although they were not intentionally designed to do so.

TABLE 8.63 UNIT DD AGING SEQUENCE

| AGING CYCLE TIME IN MONTHS | TEMPERATURE (°C) | | pH | TOTAL COLIFORM MPN ORGANISMS/100 GM | PERCENT MOISTURE | PERCENT VOLATILITY |
|---|---|---|---|---|---|---|
| | Ambient | Pile | | | | |
| 0 | 9 | 8 | 7.6 | $10^{9}$ | 74 | 77 |
| 2 | 12 | 12 | 7.2 | $10^{8}$ | 70 | 80 |
| 5 | 16 | 19 | 7.4 | $10^{10}$ | 71 | 77 |
| 1 | 19 | 28 | 8.0 | $10^{9}$ | 65 | 93 |
| 7 | 12 | 11 | 7.5 | $10^{5}$ | 71 | 76 |
| 10 | 16 | 18 | 6.9 | $10^{7}$ | 71 | 77 |

## 8.7 PIT PRIVY

Proper siting was a common failing among pit owners since most units were inundated with rainwaters. The techniques used to construct pit enclosures could be improved so as to minimize access of vectors to the pit contents. However, the attitude and practices of pit users suggests there is little appreciation of the potential sanitary hazards involved with allowing vectors unrestricted access to the excrement pile. There is no apparent explanation for the observed greater number of vectors associated with the pit privies as compared to other black waste systems apart from human indifference. It makes little sense for users to practice urine separation when the pit is 2/3 filled with rainwater as with Unit FF, or to place fly bait in the unit when the lid and door are routinely left open.

Infrequent and inadequate quantities of bulking agents probably allowed the contained excrement to give off offensive ammonia odors in addition to attracting vectors. As with the users of most other alternatives studied, the human energy required for proper operation is greatly misunderstood. A pit privy need not be infested with vectors nor smell terrible. There is a lesson to be learned from the domesticated cat with which all pit users should become acquainted.

## 8.8 OTHER CONSIDERATIONS

All of the proprietary units monitored were characterized by an accumulation of liquid within the units. The primary source of the liquid was urine although condensed moisture also was an additional source. In most units this liquid accumulation resulted in an excrement pile that was generally too moist to remain aerobic and permit biological decomposition to occur. As previously mentioned, the lack of mixing and the proper balance of nutrients (i.e., carbon/nitrogen ratio) also contributed to this problem. In general, there was a lack of understanding among the users about the operation of a biological system and the proper handling and disposal of the accumulated liquid.

### 8.81 Liquid Accumulation—Microbiological Composition

Data were collected on 13 units that experienced some degree of liquid buildup. The following is a discussion of the data with the respective units categorized according to generic type.

#### Clivus Multrum

All of the proprietary Clivus units experienced liquid retention conditions that were either ignored or attempts were made which either masked or resolved the problem. When ignored, the liquid filled the voids of the excrement solids and bedding material within the storage chamber and either slowly evaporated or overflowed outside of the unit's access door. Attempts to mask the problem included packing the storage chamber with large quantities of absorbent bedding material such as peat moss which was simply removed for disposal when it became saturated and installing an elaborate recirculation system that pumped liquid from the final compartment through a nozzle which sprayed the liquid onto the excrement pile in the storage chamber. In the latter case, the volume of retained liquid did not apparently change; it was simply redistributed. The real effect of increasing the liquid content of the excrement pile was to completely saturate the solids, thereby causing the loss of existing air voids and subsequently resulting in the collapse of the mass.

Some homeowners chose to remove the liquid for disposal. A few bailed their units by hand while two owners installed drains within the storage compartment which were plumbed to individual grey water units for subsurface leach field disposal. Unfortunately, both of these units were installed near the end of the study and could not be fully evaluated. The concept, however, bears merit and deserves further investigation since it removes the liquid from the unit and thereby reduces the amount of human contact with that liquid. It also makes a strong case for proper subsurface disposal of grey water rather than recycle schemes which could result in additional exposure to this excess liquid.

The most desirable solution, however, would require redesign of the unit with heating and adequately designed ventilation to permit necessary levels of evaporation to permit proper aerobic biological degradation to occur. Until such designs are available, solutions such as described in the preceding paragraph may be the most feasible for users of these units.

The results of microbiological testing of liquid buildup from Clivus Multrum units is shown on Table 8.81. The number of data points applies to all parameters except virus where three samples were screened.

TABLE 8.81 CLIVUS MULTRUM: MICROBIOLOGICAL FINDINGS OF ACCUMULATED LIQUID

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 ML | | BACTERIA SCREEN ISOLATIONS | PARASITE SCREEN ISOLATIONS | VIRUS SCREEN ISOLATIONS |
|---|---|---|---|---|---|---|
| | | Range | Average | | | |
| A | 7 | $10^3$–$10^6$ | $10^5$ | *Proteus*<br>*Enterobacter*<br>*Citrobacter*<br>*Klebsiella*<br>*Aeromonas* | Ciliates<br>Cysts | Reovirus |
| C | 5 | $<10^2$–$10^4$ | $<10^3$ | *Proteus*<br>*Citrobacter* | Ciliates | None isolated |
| D | 3 | $10^4$–$10^6$ | $10^5$ | Not tested | Not tested | Not tested |
| E | 10 | 10–$10^7$ | $10^4$ | Not tested | Not tested | Not tested |
| F | 10 | $10^3$–$10^5$ | $10^4$ | Not tested | Not tested | Not tested |
| G | 1 | – | $10^4$ | Not tested | Not tested | Not tested |
| H | 2 | $10^4$–$10^6$ | $10^5$ | Not tested | Not tested | Not tested |

The level of coliform indicator organisms reported on Table 8.81 for 38 samples from 7 units is surprisingly constant; most values are between $10^3$ to $10^5$ MPN. This closely approximates the coliform content of the fecal material (pile) over which it accumulates reported (on Table 8.12) as about $10^6$ MPN. Whether or not this accumulated liquid is primarily urine, it has clearly become contaminated with organisms from the excrement. Human urine from a healthy individual contains few to no detectable coliform bacteria, as does rain and air-bound moisture under normal conditions. Norwegian standards for such liquid require fecal coliform to be less than 500 per 100 ml.[84]

In addition, bacteria screens isolated *Enterobacter, Aeromonas, Citrobacter,* and *Klebsiella,* all of which are recognized human pathogens. Ciliates and cyst-like objects also survived in the liquid media although the forms observed were not known human pathogens.

Because liquids collected from confined units where human fecal matter collects differs substantially from other polluted waters in its chemical composition and properties, and because the ability to detect viruses in water often depends on water quality,[52] appropriate techniques were used to assay viruses in study samples. When two consecutive fecal samples from Unit A tested positive for reovirus, concerns were raised about whether the liquid accumulating over the fecal matter and subsequently mixing with surrounding infiltrated groundwater in the case of Unit A was also contaminated. Three liquid samples taken on consecutive months were screened. Four months after the last solid isolation, a liquid sample also screened positive for reovirus. The importance of viruses in this accumulated liquid rests in their presence. Although pathogenic bacteria must often be present in very large numbers to produce disease, even a small quantity of virus could cause human illness.[53]

Because of these findings, the liquid accumulation is judged to be capable of harboring all agents of human illness as well as being a significant detriment to the aerobic thermophilic decomposition process. It reasonably follows that conservative handling and disposal precautions are both wise and prudent. It is also clear that the primary objectives of composting cannot be realized when using a device which allows liquids to continually contact the decomposing solids, for example, inadequate evaporation capacity.

## Toa Throne

All three Toa Throne units experienced liquid retention problems which were primarily responsible for the contents not achieving aerobic thermophilic decomposition, similar to findings for the Clivus Multrum units. In addition, the results of microbiological testing as shown on Table 8.82 are similar in nature to findings for the Clivus Unit shown on Table 8.81, the total coliform content of the liquid is slightly lower than the solids over which it collects. Three samples were screened for virus with no isolations.

### TABLE 8.82 MICROBIOLOGICAL FINDINGS–TOA THRONE

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM |  | BACTERIA SCREEN ISOLATIONS | PARASITE SCREEN ISOLATIONS | VIRUS SCREEN ISOLATIONS |
|---|---|---|---|---|---|---|
|  |  | Range | Average |  |  |  |
| I | 1 | – | $10^6$ | Not tested | Ciliates<br>Cysts | Not tested |
| J | 4 | $10^4$–$10^6$ | $10^5$ | Not tested | Not tested | Not tested |
| K | 10 | $10^5$–$10^7$ | $10^6$ | *Proteus*<br>*Yersinia*<br>*Citrobacter*<br>*Enterobacter*<br>*Hafnia*<br>*Providencia*<br>*Klebsiella* | Eggs<br>Larvae<br>Ciliates<br>Flagellates | None isolated |

The results of the bacteria screen testing were slightly more diverse since Unit K was used by a limited but transient population. Pathogenic forms of *Yersinia, Citrobacter, Enterobacter, Klebsiella, Providencia,* and *Hafnia* were isolated from four liquid samples. The *Yersinia* isolation is of special interest because the organism is excreted solely in the feces of an ill individual but was isolated from the liquid above the fecal matter. The mode of disease transmission is primarily from contaminated drinking water or to a lesser extent, contaminated shellfish and dairy products. It was commonly observed that residences or locations where waterless toilets were installed usually did not have convenient or nearby handwashing facilities. Personal hygiene was generally different from standards commonly accepted for waterborne facilities. It is doubtful whether, for example, handwashing after using the toilet facilities was practiced at a large number of installations. It is certainly not unreasonable to speculate that disease transmission could occur due to lessened hygiene practices. In the case of Unit K, individuals using the unit were part of a communal teaching environment with short residence times and changeable assignments that could also include food preparation. Since this unit overflowed several times as well as being bailed-out by hand, the potential for contacting and transmitting disease organisms is not limited to the ill individual, it includes those performing system maintenance and disposal tasks as well as anyone contacting residuals left exposed to the environment.

Conditions favor pathogen survival when internal performance is similar to that observed for Units I, J, and K. *Yersinia* is known to survive and grow better at low temperatures.[49] The temperature within Unit K on the day samples containing *Yersinia* were collected was 21°C; this was greater than the average temperature recorded for all three Toa Throne units. Therefore, it could be concluded that temperatures within the minimum mesophilic decomposition range (15°–25°C) does not necessarily provide assurances of pathogen destruction. Mesophilic operations should not be relied upon for destruction of potentially hazardous disease organisms since lower temperatures favor their survival and growth.

**Bioloo**

There were no liquid samples taken from the four Bioloo Units under observation, largely because the internal rotor appeared to keep the liquid and solid wastes well combined. The liquid fraction, measured as moisture however, is the same as that quantity measured for the Mullbank Units.

**Mullbank**

Data for accumulated liquid from three Mullbank Units are shown on Table 8.83. Liquid buildup was not noted within Unit T possibly because of the infrequent rate of usage. The microbiological results shown are similar to findings for the larger units. The only apparent difference is that the capacity is much smaller necessitating a more frequent rate of removal. In addition, overflowing liquid would generally be within the residence, usually the bathroom. It follows that there is a greater likelihood of human exposure to potentially pathogenic agents contained in liquid spills from a box unit.

**TABLE 8.83 MICROBIOLOGICAL FINDINGS–MULLBANK**

| SYSTEM | NUMBER OF DATA POINTS | TOTAL COLIFORM MPN ORGANISMS/100 GM | | BACTERIA SCREEN ISOLATIONS | PARASITE SCREEN ISOLATIONS | VIRUS SCREEN ISOLATIONS |
|---|---|---|---|---|---|---|
| | | Range | Average | | | |
| Q | 2 | $10^3$–$10^4$ | $10^4$ | *Proteus*<br>*Citrobacter*<br>*Providencia* | Not tested | None isolated |
| R | 10 | 10–$10^5$ | $10^4$ | *Proteus*<br>*Citrobacter*<br>*Providencia* | Larvae<br>Cyst-like | None isolated |
| S | 6 | $10^3$–$>10^9$ | $>10^6$ | *Proteus*<br>*Providencia*<br>*Klebsiella* | Larvae<br>Eggs<br>Ciliates | Not tested |

Although this unit achieved higher temperatures, 27°–40°C, it did not reach the range necessary for pathogen destruction as evidenced by several pathogenic bacteria isolations from each of three tested units. Parasite forms surviving the higher temperatures suggest that similar forms of human parasites would also survive.

### 8.82 Liquid Accumulation—Physical and Chemical Composition

Table 8.84 shows the range of values and an arithmetic average of the number of data points indicated for the physical characteristics of liquids accumulated by certain proprietary systems. The results generally show the liquid to be high in total dissolved and suspended solids as well as high in ionic solutes as evidenced by the electrical conductivity. The values reported tend to cluster according to generic type, for example, Units I, J, and K have similar values and are all Toa Thrones. The extremely high electrical conductivity suggests that the liquid may not be of beneficial use in the case where the combined grey water and toilet liquid is subsequently used for landscape irrigation. The discussion of grey water Unit 1 contains a few data points that demonstrate the reduced chemical quality of grey water that can result when combined with this liquid.

TABLE 8.84 CHEMICAL COMPOSITION OF ACCUMULATED LIQUID

| SYSTEM | NUMBER OF DATA POINTS | pH | | TDS mg/l | | SUSPENDED SOLIDS mg/l | | ELECTRICAL CONDUCTIVITY umhos | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| A | 5 | 7.2–8.1 | 7.4 | 740–5,600 | 3,200 | 30–180 | 84 | 1,400–7,700 | 5,100 |
| C | 4 | 6.3–6.9 | 6.7 | 25,000–27,000 | 27,000 | 150–1,200 | 460 | 17,000–40,000 | 28,000 |
| D | 1 | – | 6.8 | – | 59,000 | – | 1,800 | – | 53,000 |
| E | 9 | 4.6–5.8 | 5.4 | 18,000–27,000 | 22,000 | 20–250 | 70 | 2,300–28,000 | 22,000 |
| F | 8 | 5.5–7.0 | 6.2 | 38,000–48,000 | 44,000 | 80–390 | 190 | 33,000–56,000 | 43,000 |
| H | 1 | – | 7.9 | – | 13,000 | – | 390 | – | 17,000 |
| I | 2 | 7.1–8.0 | 7.6 | 44,000–82,000 | 61,000 | 770–1,500 | 1,130 | 43,000–110,000 | 77,000 |
| J | 2 | 7.2–7.7 | 7.6 | 39,000–40,000 | 39,500 | 900–1,700 | 1,150 | 23,000–36,000 | 30,000 |
| K | 9 | 7.2–8.2 | 7.7 | 20,000–25,000 | 22,000 | 20–3,800 | 1,090 | 18,000–27,000 | 21,000 |
| Q | 1 | – | 8.6 | – | 39,000 | – | 3,600 | – | 48,000 |
| R | 7 | 7.1–8.6 | 7.9 | 18,000–280,000 | 95,000 | 590–88,000 | 15,000 | 25,000–290,000 | 78,000 |
| S | 5 | 6.5–8.5 | 7.7 | 32,000–260,000 | 130,000 | 400–66,000 | 17,000 | 95,000–250,000 | 140,000 |

Table 8.85 shows data on a few chemical parameters. Although the BOD analyses were run on all liquid samples, the reporting laboratory has stated that the data are inaccurate. The reason suggested early in the sampling program was that nitrites were suspected to be responsible for analytical interference. However, as noted by Table 8.85, apart from elevated nitrite values found with Units C, H, and J, levels of nitrites reported for the remaining nine units do not constitute the basis for difficulties encountered with the corresponding BOD analyses. Data published from two studies of sanitary landfill leachates shows the BOD and COD to be both elevated and similar in kind to one another.[54] This would suggest that a similar association could have resulted from the analyses of these samples. Another explanation suggested is that since the chemical composition is much more concentrated than that usually identified with sewage-related samples, there may be one or more constituents that are inhibitory or toxic to the primary sewage-seeded dilution water used in the test procedure.

TABLE 8.85 CHEMICAL COMPOSITION OF ACCUMULATED LIQUID

| SYSTEM | NUMBER OF DATA POINTS | COD mg/l | | TOTAL NITROGEN mg/l | | NITRITE mg/l | | NITRATE mg/l | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | Range | Average | Range | Average |
| A | 5 | 60–1,100 | 720 | 10–540 | 240 | 2–15 | 6 | 250–2,100 | 1,100 |
| C | 4 | 1,100–1,400 | 1,200 | 60–420 | 230 | 37–150 | 85 | 11,000–13,000 | 12,000 |
| D | 1 | – | 4,400 | – | 1,800 | – | <1 | – | 13,000 |
| E | 9 | 240–1,400 | 1,050 | 30–1,300 | 570 | 0.5–1.8 | 1.1 | 60–11,000 | 8,200 |
| F | 8 | 1,800–2,900 | 2,400 | 60–2,000 | 1,340 | 0.4–1.2 | 0.8 | 960–17,000 | 1,130 |
| H | 1 | – | 7,800 | – | 2,100 | – | 34 | – | 70 |
| I | 2 | 2,900–6,200 | 4,600 | 100–450 | 275 | Not tested | – | 11,000–29,000 | 20,000 |
| J | 2 | 5,500–6,800 | 6,200 | 680–800 | 740 | 27–67 | 47 | 8,500–11,000 | 9,800 |
| K | 9 | 6,300–29,000 | 11,000 | 510–890 | 670 | <0.1–2.5 | – | <0.1–114 | 15.3 |
| Q | 1 | – | 11,000 | – | 550 | – | 4.3 | – | 4.0 |
| R | 7 | 4,500–60,000 | 21,000 | 3,100–67,000 | 15,000 | 0.5–2.3 | 1.4 | <0.1–213 | <70 |
| S | 5 | 8,500–50,000 | 30,000 | 850–12,000 | 4,300 | <1–5 | 2.6 | 128.5–<10 | <46 |

The chemical pollutants of significance noted within the accumulated liquids of proprietary toilets are COD, nitrogen compounds, and total and suspended solids. BOD is suspected of being a problem but the analyses were inconclusive. These data generally show values which are greater and more variable than the levels normally associated with domestic sewage. For example, the average composition of domestic sewage total dissolved and suspended solids is 530 and 295 mg/l respectively.[55] It is likely that both the elevated and variable characteristics were due to partial and variable evaporation which concentrated pollutants in the remaining liquid.

Since it is clear that these liquid accumulations contain biological as well as chemical pollutants, two approaches can be taken. Existing toilet units could be plumbed to a subsurface disposal system if on-site disposal is acceptable; or the liquid could be transported by a septic tank pumper (or equivalent) to an approved Class II dump site for off-site disposal. Either case recognizes the risks of hazardous materials handling. If the site can accommodate it, the leach field alternative is probably more cost-effective.

The second approach is to minimize or eliminate the accumulation by preventing the problem from occurring in the first place. Most of the basic system development for composting of human wastes took place outside of the United States during the early 1900s.[56] Little refinement occurred up to and including the past few decades when energies were directed at developing increasingly complicated mechanical devices for containing the compost process.[56] This report would certainly not be the first to suggest that basic design improvements are necessary to make most areas of operation and performance more acceptable to the regulatory authorities as well as the consumers. Some of the units appear to have been designed for lower use rates and for less than full time year round usage. Most of the studied units could not under conditions of use maintain favorable aerobic decomposition conditions.

Irrespective of size and shape, all of the units utilize the same biological processes for decomposition of contained waste products. The appropriate quantity and quality of bulking agent should permit calculation of a saturation point after which other uncontrollable sources of moisture such as humidity should be removed by an improved ventilation system. Study observations repeatedly confirmed that the existing vent systems are inadequate for urine evaporation. Controllable sources of moisture such as groundwater infiltration and rainwater intrusion can reasonably be avoided by better siting and by protecting vent openings.

### 8.83 Vector Observations and Findings

#### Arthropod Occurrence

A complete list and enumeration of all the many kinds of arthropods collected by the various sampling methods from the dry toilet vaults and detailed entomological evaluation of their occurrence is not presented in this report. Data regarding the occurrence of flying insects and for mites collected on the toilet seat (and kitchen port openings where applicable) are emphasized in this report, because they represent the kinds most likely to leave the vault and invade the home or bathroom environment, or to come into direct contact with the users.

A wide assortment of flies, beetles, mites, spiders, and other arthropods were found to inhabit the dry toilet vaults. Collections of arthropod specimens actually occurring in the solids (extracted by the Tullgren funnel technique) showed mites, fly larvae, and beetles to be present in the solids of all the units examined. Mites were the most abundant kind of arthropods collected, generally occurring in numbers of 1,000 to over 100,000 per liter of solids. Fly larvae frequently occurred in numbers of 10 to 1,000 per liter, along with numerous beetles, moths, and various wingless insects. No spiders considered harmful to humans were found in the vaults. The cockroach traps were all negative for cockroaches, and after three or four traps per unit were found negative, the traps were not placed again.

Most of the arthropods found in the dry toilet vaults are known to utilize many kinds of animal and vegetable wastes for food and shelter and doubtless could be collected in the general vicinity of the sampled units in association with other accumulations of wastes such as the excrement of horses, cattle, poultry, dogs, wild animals, and birds, and in garbage cans and compost piles. In most cases, the numbers of each kind actually produced in the dry toilet solids are not likely to be significant relative to existing populations in the vicinity generated from other breeding sources. The main concern, therefore, is not the numbers of arthropods which may be produced relative to other common sources, but their association with fresh human excrement and their direct access to the user's body and bathroom environment through the toilet port. This access to both stored human wastes and the environment is not ordinarily available in conventional on-site toilet systems with an underground, sealed vault, and a water seal between the vault and the toilet opening.

Insects, mites, and other arthropods can gain entrance into the vaults by several means. The flying insects can fly through an open toilet, kitchen or access port, or they will land on the vault and crawl through small cracks or inefficient seals. Many of the gnats and small flies can pass through ordinary window screens. Several kinds of mites attach to and "hitch a ride" on flies and beetles. Another common access of importance is introduction of the eggs and larvae of flying insects, and all stages of flightless insects and mites in bedding material (e.g., forest litter and leaves) or kitchen wastes put into the vaults.

Once in the vault, many kinds of insects and mites can pass their whole life cycle in the shelter of the vault chamber, and increase their numbers rapidly and indefinitely. Examples here are the gnats and small flies including the fruit fly (*Drosophila*), and most beetles and mites. Others, including the larger domestic flies, must leave the vault to mate and cannot continue to colonize the solids without continuous access to the vault by egg-bearing females.

The medical or nuisance significance of the arthropods found in the dry toilet vaults will vary according to their habits and to different circumstances of their occurrence. The wingless insects and other unobtrusive arthropods which tend to stay in the vault once they are introduced are of little or no medical or nuisance significance. However, the flying insects commonly found in the dry toilet vaults may leave the vaults at times and become a nuisance in the home if the dry toilet is installed within the home, or in the "privy house" if it is located in a detached structure. The gnats, small flies (except *Drosophila*), and beetles are of minimal significance as vectors of disease because they do not ordinarily seek out human food, and if emanating from a detached privy house, are not likely to enter the home at all. Their possible medical significance as vectors should be acknowledged, however, as they have had access to human excrement.

The domestic flies will enter homes even if produced in a detached privy house and will frequent human food. The vector potential of the kinds found here is not considered to be as great as the common house fly (*Musca domestica*) which was not found to frequent or breed in the vaults. However, if enteric disease agents were shed into the vault, the domestic flies found in this study would be one definite way that such agents could be transmitted to other persons.

The occurrence of mites on the toilet seats of dry toilets has apparently not been reported before, and the actual nuisance or health significance of this occurrence is unknown at this time. The potential for contact with the skin of the user is obvious, however, and at least one of the kinds commonly collected has been reported to cause allergic reactions in humans. Their appearance on the kitchen ports of the Clivus is probably of little health or nuisance concern, but any invasion of the kitchen area by arthropods from the vault cannot be ignored.

## Flying Insects

The actual counts of the flying insects from each sticky tape sample for each of the individual dry toilet units are presented in graph or tabular form with each units' data package in Appendix 1. Sometimes the tapes were damaged or fell into the vault contents, but in general a valid record of the kinds and relative numbers of flying insects present was obtained. It was not confirmed by larval collection that all the kinds reported from the tapes were actually breeding in the vault contents, but when large numbers of a certain kind were consistenly found, it is reasonable to conclude that the species was breeding there, as opposed to being attracted into the vault for feeding purposes only. In interpreting the sticky tape counts, it should be noted that counts over 100 are estimates, and that tapes may dry out at different rates in the vaults. Also the numbers per tape simply reflect insect occurrence in the vaults and are not necessarily related to the actual total numbers present or to actual numbers escaping from the vaults.

A detailed interpretation and analysis of the seasonal occurrence and relative abundance of the flying insects as reported for the individual units is not presented here, as this report is intended to emphasize the general performance of the various dry toilets. The data are used to provide a basis for the summary tables and to document the statements which follow in this section concerning the response of the insect populations in the individual units to management conditions and attempted control measures.

A list of the flying insects commonly found in the dry toilet vaults during this investigation, and their occurrence in the seven generic types of units is presented in Table 8.86. The occurrence of the flies and moths was determined from the sticky fly tape collections. The beetles, which fly only infrequently, were determined from the solids extraction collections.

The Psychodidae, Fungivoridae, and Scatopsidae are mainly very small, soft-bodied flies which are weak fliers and which feed as larvae mainly on fungi and molds. They resemble small mosquitos in appearance and are collectively called "gnats" in this report. The Phoridae, Milichiidae, Spaeroceridae, and Heleomyzidae are generally larger than the gnats and resemble miniature typical flies to the unaided eye. These families, called here "small flies," feed on animal excrement as larvae, and the adults are stronger flies than the gnats. Both the gnats and small flies were found in large numbers at times in the dry toilet vaults, and are considered nuisance flies because they were found to appear in the bathroom or privy house when large numbers were breeding in the toilet vaults. However, they actively seek escape from enclosed rooms and do not frequent human food.

The *Drosophila* (family Drosophilidae) are related to the small flies taxonomically, but are not grouped with the other small flies because of their habits. They feed on fruit wastes as larvae, and are considered domestic flies because they tend to stay in the home as adults and feed on human food. The species mainly found were *Drosophila busckii*, but *D. melanogaster* and *D. immigrans* were also found. Flies in the Genus *Drosophila* are collectively called "fruit flies."

## TABLE 8.86 FLYING INSECTS COMMONLY FOUND IN THE WATERLESS TOILET VAULTS*

| | TOTAL NUMBER OF UNITS | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | 3 | 4 | 4 | 5 | 4 | 5 |
| | Clivus | Toa Throne | Mullbank | Bioloo | Vault | Drum | Pit |
| **FLIES (Diptera)** | | | | | | | |
| Gnats (Nematocera) | | | | | | | |
| Psychodidae | 6** | 2 | 0 | 1 | 5 | 1 | 5 |
| Fungivoridae | 7 | 2 | 1 | 1 | 5 | 4 | 5 |
| Scatopsidae | 7 | 3 | 1 | 1 | 5 | 4 | 4 |
| Small Flies (Acalyptcrate Muscoid Flies) | | | | | | | |
| Phoridae | 6 | 2 | 3 | 2 | 5 | 4 | 5 |
| Milichiidae | 7 | 2 | 3 | 4 | 5 | 4 | 5 |
| Sphaeroceridae | 6 | 2 | 4 | 3 | 5 | 3 | 4 |
| Heleomyziidae | 2 | 1 | 1 | 2 | 5 | 2 | 5 |
| *Drosophila**** | 5 | 1 | 0 | 0 | 0 | 2 | 0 |
| Large Flies (Calypterate Muscoid Flies) | | | | | | | |
| *Fannia**** | 4 | 3 | 3 | 4 | 5 | 4 | 5 |
| *Muscina**** | 3 | 2 | 1 | 2 | 5 | 4 | 5 |
| *Ophyra**** | 3 | 2 | 1 | 2 | 5 | 3 | 3 |
| Calliphoridae*** | 2 | 0 | 2 | 1 | 5 | 1 | 5 |
| **BEETLES (Coleoptera)** | | | | | | | |
| Nitidulidae | 6 | 2 | 0 | 0 | 2 | 0 | NS |
| Staphylinidae | 6 | 3 | 4 | 0 | 5 | 3 | NS |
| Histeridae | 5 | 1 | 3 | 1 | 5 | 3 | NS |
| **MOTHS (Lepidoptera)** | | | | | | | |
| Pyralidae | 6 | 2 | 0 | 2 | 0 | 2 | 0 |

* Fly and moth occurrence from sticky tape counts; beetle occurrence from solids extraction counts.
** Number of units positive for the insect group.
*** Domestic flies.

The "large flies" reported in Table 8.86 are all domestic flies, and were the most important kinds of insects found in the dry toilet vaults. The *Fannia* include some *F. canicularis* (the little house fly), but mostly *F. scalaris* (the latrine fly). *Muscina* (false stable flies) includes *M. assimilis* and *M. stabulans; Ophyra* (black garbage flies) includes *O. leucostoma* and *O. aenescens*. The Calliphoridae (blowflies) were mainly *Eucalliphora lilaea, Aldrichina grahami* and *Phaenicia sericata*. These domestic flies feed on animal excrement and decaying vegetable matter, as both larvae and adults, and the adults feed on human food. Because their habits and the implications of their occurrence are similar, they are collectively referred to as "large flies" in this report.

The last flying insects worthy of mention here are the moths and beetles, which may cause a nuisance in the home or privy house at times but are not considered very important compared with the gnats and small flies. The beetles of the Family Nitidulidae feed on fruit wastes as adults and larvae, and the Staphylinidae and Histeridae feed on fly larvae and other insects. These latter two kinds may serve as important biological control agents of domestic and nuisance flies in the vaults. The small moths found in large numbers at times in the Clivus and Toa Throne vaults were identified as *Pyralis farinalis*, the "meal snout-moth," and invaded the home in noticeable numbers on occasion.

In order to evaluate and compare the performance of the dry toilet units in regard to the occurrence of nuisance and domestic flies, the counts from the sticky tape collections have been summarized for all reported units in Table 8.87. The families of flies in the categories of gnats and small flies were grouped together, as were the larger domestic flies. *Drosophila* is reported separately to allow a better comparison of the occurrence of the larger domestic flies between unit types.

Gnats and small flies were found to occur at times in all of the 33 dry toilet units reported here. Domestic flies were found in all units except Clivus units C, E, and H and Mullbank unit T. Of a total of 344 sticky tape samples taken from the vaults, during this 15-month study, only 2 were negative for flies.

The data as summarized in Table 8.87 show that gnats occurred in similar numbers in all of the unit types except the Mullbank and Bioloo. The small flies also occurred in relatively similar numbers in the vaults except in the Bioloo units. The high counts of these nuisance flies obtained for most of the units can be explained by their small size and their ability to reproduce and increase in numbers without leaving the vault, once they become established.

The low number of flies in Bioloo units is probably explained by the high pile temperatures, and the fact that the solids are mixed frequently with the rotor, thus suffocating the eggs and larvae. The presence of large numbers of small flies in the Mullbank, but the very low occurrence of gnats, may also be related to temperature conditions in the solids. Gnats prefer cool conditions and the heating coils in these units probably kept the solids heated above their tolerance levels. The small flies, however, prefer warmer conditions and colonized the outer layer of the unmixed piles in these units.

Of the domestic flies, *Drosophila* were found mainly in four Clivus and two Toa Throne units, obviously associated with kitchen garbage and fruit wastes added to these units. The reason for their appearance on one occasion in each of the two drum privy units (CC and DD) was not evident.

The large domestic flies of most significance as possible disease vectors occurred in relatively low numbers in the four proprietary units. These factory-made plastic and fiberglass units offered the least access to the large flies because of the well-sealed vaults and the fact that they were installed within the residences. The high numbers in Clivus unit A were taken on the three positive tapes right after unit start-up, and during a time when the kitchen port cover had not been installed. After this three-month period, large flies were not found again. The high counts for Bioloo unit X were taken when the unit's rotor was broken and pile conditions were very bad. The lower, but significant counts for Bioloo unit U, were reflective of a *Fannia* infestation in the unit, but the source of larval occurrence was not found. The very low counts in all the Mullbank units and Bioloo units V and W probably resulted from flies in the house being attracted into the units, and no evidence of larval development was found.

The data show that the large domestic flies occurred in high numbers and were developing as larvae in all of the owner-built units except drum unit DD and the finished solids chamber of vault unit O. These high counts were associated with inadequate seals around access doors and vents, and with easier fly access to the toilet ports and storage vaults due to their placement in ineffectively screened, detached privy houses. Drum unit DD was effectively sealed and screened and well maintained. The larger domestic flies were found to occur in high numbers in both the fresh (in-use) chamber and the finished (storage) chamber of vault units L, M, and N. Fewer large flies were found in vault units O and P. These two units had much more limited use than the other three, and the solids in both chambers of O and P were found to be consistently in a very dry condition. Unit P, which had the lowest large fly occurrence overall, was the best constructed and sealed unit of the five vault privies.

## TABLE 8.87 SUMMARY OF NUISANCE AND DOMESTIC FLY OCCURRENCE IN THE WATERLESS TOILET VAULTS

| | UNIT | NUMBER OF TAPES COUNTED | NUISANCE FLIES | | DOMESTIC FLIES | |
|---|---|---|---|---|---|---|
| | | | Gnats | Small Flies | *Drosophila* | Large Flies |
| Clivus | A | 7 | 3/283* | 7/187 | 1/5 | 3/80 |
| | B | 8 | 8/1,074 | 6/128 | 4/54 | 5/19 |
| | C | 9 | 9/363 | 4/105 | – | – |
| | D | 15 | – | 14/827 | – | 1/1 |
| | E | 10 | 10/120 | 9/64 | 3/23 | – |
| | F | 14 | 14/317 | 14/469 | 13/581 | 10/7 |
| | G | 6 | 5/118 | 6/179 | 5/170 | 3/18 |
| | H | 4 | 4/130 | – | – | – |
| Toa Throne | I | 4 | 2/350 | 4/150 | – | 2/22 |
| | J | 4 | 4/93 | 4/64 | 2/150 | 1/20 |
| | K | 16 | 16/303 | 16/226 | 6/22 | 12/26 |
| Mullbank | Q | 9 | 1/20 | 9/170 | – | 1/2 |
| | R | 10 | 2/5 | 10/749 | – | 5/3 |
| | S | 4 | – | 4/626 | – | 2/2 |
| | T | 8 | – | 8/765 | – | – |
| Bioloo | U | 7 | 5/21 | 5/7 | – | 6/31 |
| | V | 6 | – | 5/15 | – | 6/7 |
| | W | 7 | 2/2 | 6/53 | – | 2/2 |
| | X | 2 | 1/10 | 2/40 | – | 2/145 |
| Vault (Fresh Chamber) | L | 11 | 11/339 | 11/142 | – | 11/320 |
| | M | 11 | 8/108 | 10/185 | – | 10/254 |
| | N | 12 | 12/428 | 10/177 | – | 11/194 |
| | O | 12 | 11/106 | 8/82 | – | 9/30 |
| | P | 11 | 11/65 | 11/241 | – | 9/33 |
| Vault (Finished Chamber) | L | 11 | 11/188 | 8/155 | – | 10/213 |
| | M | 8 | 6/99 | 8/109 | – | 8/158 |
| | N | 12 | 12/819 | 8/129 | – | 8/131 |
| | O | 12 | 8/29 | 9/10 | – | 8/2 |
| | P | 10 | 10/52 | 6/157 | – | 4/72 |
| Drum | AA | 10 | 5/112 | 10/102 | – | 9/172 |
| | BB | 6 | 3/91 | 3/436 | – | 6/130 |
| | CC | 6 | 4/58 | 6/235 | 1/100 | 4/65 |
| | DD | 11 | 7/262 | 11/404 | 1/5 | 4/10 |
| Pit | EE | 12 | 11/823 | 5/217 | – | 5/125 |
| | FF | 9 | 8/188 | 7/387 | – | 9/313 |
| | GG | 9 | 9/182 | 6/180 | – | 9/382 |
| | HH | 11 | 11/141 | 9/157 | – | 11/206 |
| | II | 10 | 9/210 | 9/47 | – | 10/85 |

* Number of Tapes Positive/Average Numbers per Positive Tape.

The five-pit privy units which were studied had the most consistently high counts of large domestic flies found during the study period. So that this poor performance does not unduly condemn pit privies in general, it should be pointed out that none of the five units were constructed and operated as classically designed sanitary pit privies. None of the five units had efficiently screened houses and well-sealed toilet seat covers. The pits were not lined with wood and the users did not lime the solids periodically. Units GG, HH, and II had very oversized pits which allowed the solids to spread out and be generally suitable for fly larval development. The results indicate that pit privies must be constructed according to designs proven by past experience to minimize fly occurrence, or excessive numbers will be found.

The data presented and discussed above show that nuisance and domestic flies occurred in significant numbers at times in almost all the units investigated. Whether these flies posed a problem to the users and whether control measures were taken or not varied as to the user's tolerance level and the extent of invasion of the home or privy house. Reports of insect problems and control measures are summarized from the field investigator's monthly reports which are reported in Section 6. Of those respondents to the needs survey shown in Appendix 3, 74 percent indicated that they had experienced problems with insects emerging from the vaults. All of the Clivus, Toa Throne, and Mullbank users reported problems, whereas only one Bioloo user so reported. Of the owner-built units, only two of five vault privy users reported a problem, two of two-drum privy users had a problem, but two of two-pit privy users reported no problem. Those respondents that reported taking control measures also reported that such measures were very to moderately effective in all but two cases.

In summary, domestic fly occurrence in the proprietary units (Clivus, Toa Throne, Mullbank, and Bioloo), although common, was not excessive and seemed to be controllable when necessary by the dedicated user. Because these units were installed in the home, flies escaping the vaults were more noticeable and their occurrence necessitated control measures by the occupants. The high numbers of large domestic flies found in the drum, vault, and pit privies were not as apparent to the users, and few people made special efforts to control them. However, whether or not these large flies posed a nuisance problem to the occupants, their presence indicates gross exposure of possible vectors to human excrement which should not be tolerated. The owner-built units must be carefully constructed and constantly maintained to prevent significant access and breeding by domestic flies.

### Mites on Toilet Seats and Kitchen Ports

The results of the flannel cloth swab samples, taken on the toilet seats and adjacent chute area of all of the dry toilet units, and on the kitchen ports of seven Clivus units, show that mites crawl up the chute and appear at times on these parts of the structural unit. The actual counts for each unit are presented in tabular form or on bar graphs and are included with each units' data package in Appendix 1. These data have been summarized as Table 8.88.

A total of 375 swabs were examined of which 168 (45 percent) were positive for mites. Mites were found to occur on the toilet seat swabs of all the units except Clivus unit C and pit privy unit FF. A total of 43 swabs (25 percent) were found to have counts of 10 or more, and the highest number counted on one swab was 189.

In order to determine if mite occurrence on the toilet seats was related to the occurrence of mites in the solids samples, the mites collected per liter of solids by the extraction technique were enumerated for nine representative units (Clivus–A, D, E; Toa Throne–K; Mullbank–R; Bioloo–V; vault–O, P; and drum–DD). The results appear on the mite swab bar graphs for these units in Appendix 1. A perusal of these graphs indicates that there was apparently no relationship between changes in numbers of mites in the solids and the time of their appearance on the seats and kitchen ports.

The Bioloo units had the lowest numbers of positive swabs and as well the lowest numbers of mites per swab taken. This was probably related to the fact that the fewest numbers of mites occurred in the solids of these units, which were heated and mixed by the rotor with each use. Also, very few mites were found on the pit privy seats, which in this case was probably related to the distance of the toilet seats from the mass of accumulated wastes.

### TABLE 8.88 SUMMARY OF MITE COUNTS FROM TOILET SEAT AND KITCHEN PORT SWABS

| UNIT TYPE | NUMBER OF UNITS SWABBED | NUMBER OF UNITS POSITIVE FOR MITES | NUMBER OF SWABS TAKEN | PERCENT OF SWABS POSITIVE FOR MITES | NUMBER OF POSITIVE SWABS WITH 10 OR MORE | HIGHEST COUNT |
|---|---|---|---|---|---|---|
| Clivus | | | | | | |
| Toilet seat | 8 | 7 | 71 | 37 | 3 | 155 |
| Kitchen port | 7 | 7 | 62 | 47 | 10 | 150 |
| Toa Throne | 3 | 3 | 26 | 61 | 6 | 115 |
| Mullbank | 4 | 4 | 42 | 55 | 7 | 120 |
| Bioloo | 4 | 4 | 31 | 22 | 1 | 12 |
| Vault | 5 | 5 | 57 | 46 | 6 | 115 |
| Drum | 4 | 4 | 43 | 70 | 10 | 189 |
| Pit | 5 | 4 | 43 | 25 | 0 | 7 |

The highest swab count of 189 was from drum unit BB, and was taken at a time when the drum was full and the solids were in contact with the toilet seat chute. The unit that showed the most consistent high counts was Toa Throne unit K, which had 4 successive high counts (20–115) during the period October 1979 through January 1980. These counts were apparently related to the fact that the pile of accumulated solids was actually touching the chute at this time.

In regard to the Clivus units with kitchen ports, the data show that mites occurred in consistently higher numbers on the kitchen ports than on the toilet seats. No observations or data were obtained that would explain this phenomenon.

The mites which have been identified from the swabs were found to represent 15 families. However, most of the specimens are of five, which are listed below in their order of abundance, with brief comments on their known habits.

1. *Acaridae.* These specimens were mostly *Tyrophagus putrescentiae,* the common stored-food mite. Unlike many other arthropods invading stored food, these mites require a high relative humidity. These mites have been associated with allergic reactions in humans.
2. *Uropodidae.* These mites are fungus feeders and commonly found in forest litter.
3. *Macrochelidae.* Mites of this family feed on fly eggs and small fly larvae.
4. *Ascidae.* Little known forms which are thought to be predators on other mites.
5. *Anoetidae.* These mites were collected as hypopi, which is a nonfeeding immature stage adapted for dispersal.

It is worthy of note that small fly larvae were found alive on three swabs from Toa Throne unit K and one swab from pit privy unit EE. These larvae were early instar small flies which could not be definitely identified to Family. However, some have been tentatively identified as Phoridae, which have been implicated in genital myiasis of female humans.[44] During the time fly larvae were found on the seat of the Toa Throne unit 1, the solids in the vault were actually touching the lower lip of the chute. The pit privy occurrence was in December and can perhaps be explained by very humid conditions in the vault allowing the larvae to crawl up the wooden sides.

**Prevention and Control**

The total exclusion of arthropods from an aerobic dry toilet vault containing human wastes is probably impossible and not necessarily desirable. The burrowing activity of fly larvae, beetles, and mites may increase aeration in the solids pile and enhance decomposition.[58] However, the potential for rapid proliferation of flying insects and mites capable of invading the home necessitates careful management of the units and effective control measures when problems arise.

Approaches to the prevention and control of problem insects involve exclusion, habitat modification, and insecticide use. Because domestic flies (except *Drosophila*) cannot continuously breed in the vaults, exclusion will effectively stop an infestation. Regular 16 mesh window screen will exclude these flies and should be used to cover all vents. Access ports should be tight and well-sealed and the toilet seat port should have a tight lid which is easy to keep closed when not in use. To prevent introduction of fly eggs and larvae into the vault, kitchen garbage should not be exposed to flies before being put into the vault.

The gnats and small flies (including *Drosophila*) which colonize the vaults are difficult to prevent by exclusion because most of the kinds found can get through a 16 mesh screen and theoretically it takes only one female of a species to start an infestation. Smaller mesh vent screens are not recommended as they are susceptible to rapid clogging with dust and fine particles. Habitat modification, such as frequent covering of the wastes with additives (e.g., sawdust or wood ashes) was reported by several occupants to suppress small flies and gnats. For problems with fruit waste breeding kinds, such as *Drosophila* and fruit-waste beetles (Nitidulidae), exclusion of kitchen garbage from the vaults may be necessary. Raising pile temperatures with heating elements and mixing of the solids after each use, as was possible with the Bioloo units, are also types of habitat modification which seemed to suppress problem arthropods.

Insecticide control was reported to be effective by several occupants, but no controlled tests have been done. Pressurized household insecticide spray cans were used to fog the vaults to kill adult flies, but this did not seem to affect the eggs and larvae in the pile, necessitating frequent applications. Vaporizing insecticide strips which continuously dispense an insecticide gas were reported effective by some users. However, the efficiency of these devices depends upon accumulation of vapor in the vault which would not occur in a well-ventilated vault.

Mites probably cannot be controlled in a dry toilet vault by any of the methods discussed above. Their occurrence on the toilet seat or kitchen port can be minimized by frequent cleaning of these parts, occurrence on the toilet seat or kitchen port can be minimized by frequent cleaning of these parts, and by not allowing the solids pile to contact the lower end of the chute.

## 8.9 COMPARISON OF FIELD FINDINGS TO HEALTH EVALUATION COMMITTEE CONCLUSIONS

The purpose of the Health Evaluation Committee's Risk Assessment, which was described in Section 4.5, is to present a decision-making tool that could be used in assessing the public health risks of on-site waste treatment and disposal systems. The technique provides for a relatively objective comparison of health risks between on-site systems alternatives. The approach forces the decision maker to consider many factors relevant to the operation of on-site systems collectively and to make explicit health risk judgments concerning any given system.

An objective technique for regulatory decision making is vitally necessary if alternative technologies for treatment and disposal of household wastes are to be supported and encouraged. It is quite evident that soil and other site conditions render the traditional septic tank system unsuitable in many areas. Alternative technologies may offer the possibility of safe treatment and disposal of household wastes on land which could not otherwise be developed. However, since review criteria for alternative technologies are largely undefined, regulatory officials often make decisions in an atmosphere of pressure brought to bear by the would-be developer and the would-be supplier of the alternative system under review.

In response to development pressures, governmental bodies and regulatory agencies have been forced into rapid decision making without sufficient quantitative information on the risks involved. For example, a real danger exists when a reviewing agency prohibits the use of a septic tank system only to approve an alternative system that is even more unsuitable. Without reliable knowledge of the implications and consequences, the decision makers' ability to make sound judgements is diminished. Since the fundamental purpose of all waste treatment and disposal systems is to protect public health, the decision maker must ensure that on-site waste treatment and disposal systems achieve this protection. The first step in achieving this goal is of course to assess the public health risk incurred with the use of on-site systems.

Two basic approaches exist for the decision maker: one can wait indefinitely until sufficient data to generate a theory are available and then test the hypothesis; or, one can make the best of an admittedly unsatisfactory situation and try to ascertain the relevant intuitive insights of experts and then use their judgments as systematically as possible. No justification is made for the validity of the Delphi approach used in this study to determine the health risk assessment in following the latter approach. The following compares the findings of the field study with preliminary insights from using this opinion consensus technique.

In applying the health risk assessment approach, the Health Evaluation Committee (HEC) agreed that the impact of the following factors should be given special consideration: disposal system conditions, end-product disposal, system maintenance, and disease morbidity in the associated population.

### Disposal System Conditions

The results of the health risk assessment determined that climate and population density play the predominant role in the determination of estimated risk values. Climate was considered a major variable since conditions of temperature, rainfall, and sunlight have a significant impact upon the survival and transport of disease agents that might be present in black waste or grey water. A desert climate was associated with the least risk, while mountain and coastal climates were felt to constitute a somewhat greater hazard by providing more favorable environmental conditions for the objectionable organisms.

The results of the field findings supports this HEC determination. Coastal and mountain waterless toilets were affected by climatic conditions not likely to occur in a desert setting; however, none of the waterless toilets evaluated were in a desert environment. Improper siting was usually responsible for intruding stormwaters. The internal temperatures were cold enough to favor the survival of viral and bacterial pathogens. In adas vaults and drums that relied on solar heat and/or time for decomposition recorded lower temperatures during the wet, cold months that indicated little or no decomposition was occurring. Two desert untreated grey water sites contained approximately half as many coliform organisms as an untreated coastal grey water site.

On the issue of population density, HEC judged that the incremental risk doubled when going from a low density condition to a high density condition of less than one acre per system. This cutoff point appears to be consistent with the Environmental Protection Agency definition of a closely populated area as given in its Program Requirements Memorandum No. 77-8 as one system per two acres. The field findings neither support nor refute this issue.

### End Product Disposal

HEC judged that the degree of risk is dependent upon final disposal or use of the black wastes and that the user should receive further guidance on land disposal. The risks tend to increase in the following order: bury; landscape; food crop. The risks associated with the wastes are greatest when the wastes are placed on the land surface where food crops and/or people could become contaminated. The findings of the field study suggest that this is a possibility since all forms of pathogenic organisms can and would likely survive the tested units in the absence of thermophilic decomposition. The quality of the final products tested within the study would suggest either on-site burial or appropriate off-site waste disposal; in any case, the residuals were in need of significant waste treatment. The field findings demonstrated that the residuals contained pathogenic organisms, degradable organics, odors, vectors, and were heterogeneous and fairly wet.

### System Maintenance

HEC review of the field data on maintenance indicated that maintenance of the drum, vault, and proprietary toilets with an accompanying grey water system presented more of a health risk than that of the septic tank-soil absorption systems. However, the Committee felt that due to maintenance considerations, the degree of change in health risk would be minor in most instances and would not constitute a major impact on the overall public health risk value. This does not mean, however, that improper maintenance would not increase the risk to individuals involved in such a maintenance activity.

It was the opinion of the Committee that in heavily populated areas, the impact of system maintenance becomes more critical to satisfactory system performance. In such instances, the Committee felt that community-based or structured maintenance programs would merit consideration.

### Disease Morbidity in Associated Populations

The health risks from on-site systems vary according to local conditions. Within the United States, reported enteric infectious disease morbidity is generally low and, consequently, concentrations of these agents are low and dose contact limited. Thus, documented disease incidents associated with on-site systems are rare events. However, mention should be made of the potential problem posed by persons traveling through or from abroad which could possibly result in new foci of soilborne nematodes and other intestinal parasites.

The field findings generally support HEC projections in that there were few actual isolations of infectious disease agents and only one documented disease incident. The Salmonella, Trichuriasis, and reovirus isolations were at households without reported active cases of each respective illness. It was not technologically possible to isolate the viral agent from the site with a confirmed case of infectious hepatitis.

Conditions outside of the United States are very different, especially in less developed and highly populated countries. In the latter countries, the reported morbidity levels are high, concentrations of infectious agents are great, and agent-host contact highly probable. In such situations, separating documented on-site system-associated disease from existing high levels of morbidity will prove difficult and make use of the health risk assessment results tenuous. On the other hand, in areas that are not presently benefited by proper sanitation, the use of on-site systems would generally be considered a major asset in the improvement of community health. Because of the differences involved, the health risk values generated by the Committee are applicable to the United States and not necessarily to other countries. However, for the latter, the same risk assessment approach may be used to estimate values appropriate to local conditions.

# SECTION 9
# MODEL EDUCATION FRAMEWORK

Both users and regulatory officials have expressed the need for an education program concerning on-site systems. Whereas the regulatory body usually has ample information for decision making regarding the septic-tank soil absorption system, little information has been formally developed for dry toilets and grey water reuse systems. The educational background in this section is a framework based on an assessment of user and regulatory officials' needs as well as the information developed from the field observations.

**This framework is not intended to be a complete education package.** It is the foundation upon which health officials, educators, and regulators may develop individual education programs. The framework will assist in educating officials about the best known procedure for installing, operating, and maintaining waterless toilets and grey water reuse systems. It will suggest the extent of regulatory activity required by these alternatives.

The framework is adaptable to a wide range of physical and political environments. It can be shaped by local officials into slide, lecture, pamphlet, or other forms of presentation using the degree of advice and regulation deemed necessary. The objective of the framework is to shape a practical program for regulatory officials and health educators who have the responsibility for educating the sanitarian and user.

The model education program has been divided into five topics: composting, design and installation, maintenance and operation, health aspects, and management by local agencies. For each topic a discussion follows specifying the information required by health educators to develop individual programs.

## 9.1 COMPOSTING

Although anaerobic biological decomposition is the predominant process in the pit privy and the septic tank, the desired process in waterless toilets is aerobic biological decomposition. In general, the aerobic process is faster, does not produce foul odors, and decomposes solids into a stabilized soil-like material. Several conditions must be met to insure that aerobic decomposition processes proceed uninhibited. A thorough discussion of key process determinants appears in Section 4.1.

## 9.2 DESIGN AND INSTALLATION OF WATERLESS TOILETS

A good waterless toilet design is one that aids the aerobic decomposition process and minimizes human contact with the excrement. Since there is little user control over some of the following design features, the proprietary system user should be aware of each consideration when choosing a unit for purchase. Features that should be in the design of every waterless toilet are as follows.

### Ventilation

The ventilation system is responsible for maintaining air circulation about the composting pile, and for removing excess moisture and odors. The system basically consists of vent openings and an exhaust pipe which is usually aided by an electric fan. The vent exhaust pipe should be as straight as possible and insulated outside to decrease condensation. It should extend to two feet above the roof line of the house to allow adequate air flow to take place. The exhaust pipe should be an open-type stack with rain cap that has a minimum diameter of ten inches when no forced ventilation is used. Fan capacity should be sufficient to evaporate excess liquid from pile.

### Heat Retention

The chamber walls should be constructed of a thermally insulated, nonconductive building material. External heat sources have been demonstrated beneficial to the biological decomposition process in biological toilets. The only units approved by the Norwegian testing program for year around usage employ electric heating elements in addition to sufficient fan capacity to insure sufficient water evaporation.

**Moisture Control**

Adequate quantities of an appropriate bulking agent must be used both to accommodate expected quantities of urine (large units, e.g., Clivus, only) and to provide the structural integrity (porosity) necessary for biological decomposition to occur within the excrement pile. Section 4.1 contains specific information on bulking agents and moisture levels. If urine quantities are still a problem, plumbing the unit to a subsurface leach field may resolve the matter.

**Vector Exclusion**

As discussed in Section 4.3, vectors can transmit both pathogens and be a nuisance. Vectors can be excluded by screening vents and openings with 16-mesh copper screen, by sealing toilet cover and seat openings, and by tight toilet room enclosure construction using vector-proof windows and doors.

**Structural Soundness and Capacity**

To insure the toilet structure is capable of carrying out its intended function, the unit requires a strong foundation and should be constructed of adequate building materials. The unit should be sized based upon facts from actual use information with acceptable levels of performance. The toilet unit should contain adequate provisions for access for mixing and removal of the finished product.

**Location**

All portions of the waterless toilet should be sited to eliminate the possibility of contact with surface, ground, or drinking water. Wind and solar access should also be considered in situations where either affects unit performance. For example, trees may cut off circulation from the roof vent.

## 9.3 DESIGN AND INSTALLATION OF GREY WATER SYSTEMS

Any grey water reuse system design is dependent on the volume of wastewater, its characteristics, and the disposal site. Features that should be in the design of every grey water system are as follows.

**Adequate Capacity**

Each system needs to be designed to handle the anticipated flow in both tank and leach field. Sizing may be dependent on past utility consumption or lifestyle characteristics of the given community and may suggest that a reduction from the conventional septic tank system is appropriate.

**Location**

The same environmental concerns that apply to septic tank systems apply to grey water units. They insure that the grey water does not directly contact surface, ground, or drinking waters. Factors such as percolation rate, slope, and distance to other waters are important.

**Functional**

The unit should be capable of performing necessary wastewater treatment functions such as grease removal to prevent clogging and to remove excess particulate matter.

**Subsurface Disposal**

Subsurface disposal reduces health risks and allows the wastewaters to achieve levels of treatment by percolating through the unsaturated soil mantle.

Other design features which apply to all waterless toilets and grey water reuse systems are well-marked tools, provisions for backup systems, and knowledge of the manufacturer's recommended practices.

## 9.4 MAINTENANCE AND OPERATION

This study and previous studies have shown that the vast majority of users will not perform needed operation and maintenance properly. However, individual on-site wastewater as well as segregated black and grey waste systems demand that the user accept the responsibility for the proper treatment and disposal of his waste products. The user must accept this responsibility because individual systems require regular maintenance to insure consistent and trouble-free operation. Without regular maintenance, health risks and a variety of aesthetically unpleasant problems will result. For example, existing dry toilets require proper amounts of bulking additives as well as frequent mixing to maintain aerobic conditions necessary for biological decomposition to occur. Without regular and frequent attention, the waste pile quickly becomes anaerobic; decomposition slows significantly, odors proliferate, and vectors are attracted to the wastes. With regular maintenance, deviations from the aerobic process should be easily recognized and remedied before larger problems develop. A typical base line maintenance schedule for waterless toilets should include the following.

### Start-up

A proper start-up is important to the future operation of a waterless toilet. In the case of a proprietary unit, the manufacturer's instructions should be followed carefully. Start-up of all units involves spreading a bulky material such as peat moss, soil, straw, or sawdust on the bottom of the unit. This material functions as the base of the composting pile as well as a source of limited nutrients when the pile is mixed. The initial layer of bulking agent should be at least 6 to 9 inches deep and composed of combustible refuse of appropriate quality. A thorough discussion of bulking agents appears in Section 4.1.

### Mixing

Natural ventilation is not adequate to supply the quantity of air necessary to keep the composting pile aerobic. Mechanical mixing or turning is usually necessary to maintain aerobic conditions. The amount of mixing necessary at a site is governed primarily by the moisture content and to a lesser extent by the type of materials being composted. Section 4.1 contains a discussion of those factors governing the necessity for and frequency of mixing.

### Inspection

Problems may involve either the internal process or the external container. A regular inspection program will assist in identifying areas which are in need of attention before major problems develop. A good place to start is with a visual check of the unit's hardware. Metal parts such as doors, bolts, and screens should be examined for damage or rust. Seals, screens, and insulation should be vector-proof and in good condition. Mechanical parts such as heaters, fans, handles, rotors, and/or topping bars should be examined for their ability to carry out their designed function. Vent openings should be kept clear of obstructions. The chamber itself should be of sound structural integrity with an adequate supporting foundation. Inspection of the composting pile itself is probably the most important check a user can make. Visual techniques for determining the progress of the process are discussed in Section 4.1.

### Problem Solving

**Moisture**—Liquid accumulations were found to be a common problem with proprietary toilets. Mitigation measures include ascertaining whether all key process determinants for biological composting have been fulfilled; determining whether the ventilation system is functioning properly; and/or plumbing the liquid to a subsurface disposal leach field. Systems with infrequent or minimal use rates may suffer from too little moisture, and therefore need to have water added by spraying.

**Odors**—Accumulated liquid and a clogged vent system may be responsible for odors. Both of these subjects have been previously discussed. Generally, ammonia and hydrogen sulfide odors indicates that the composting pile has become anaerobic. Section 4.1 discusses the interrelated factors of the composting process.

**Vectors**—The best way to control vectors is to keep them out of the unit. Since vectors can enter the toilet system through vent and chute openings, it is important to screen all air openings such as vent pipes, air intakes, and windows. A 16-mesh copper will exclude the tiny fruit flies. The toilet seat should have two seals; one between the seat and the stool, and the other between the seat and the lid. A frequently mixed, actively composting pile will not be attractive to insects. Rather than resorting to potentially toxic insecticides, vector control can often be effected by assuring that conditions are correct for aerobic biological composting.

**Disposal**

The final disposal of residuals from a waterless system should be consistent with local policy and regulation. If on-site disposal is authorized, it should be by burial in a place where it will remain undisturbed under 12 inches of soil near, for example, fruit trees, berry bushes, or ornamental trees and shrubs. A typical maintenance schedule for a grey water system should include the following:

**Inspection**—Periodic inspections will help prevent health and nuisance problems from developing. Keeping all parts of the system clean and operative will greatly reduce system failures. Distribution lines, for example, can easily be clogged by grease or particulates. Frequent cleaning or servicing will remedy the problem. Surfacing effluent can result from a saturated leach field or from overloading the unit. Remedies include either increasing the capacity of the system or by reducing flows through the existing unit. All mechanical and physical components are subject to wear with use and exposure to the environment. They should be repaired and/or replaced as necessary. Easily damaged parts should be replaced with spare parts.

**Plant Injury**—Chemical constituents in the grey water may not be tolerated by certain types of plants. Either the leach field in use could be changed to another with more tolerant plants or the offending substance simply not put into the system. It may be appropriate to divert poor quality grey water to another disposal system. The grey water reuse system may simply use the better quality household grey waters and defer the remainder to the subsurface disposal system used during nonirrigation periods.

## 9.5 HEALTH ASPECTS

Health and regulatory officials are concerned with the possibility of human contact with the wastes and waste products, and with the likelihood of surface and/or groundwater contamination. Unit design, maintenance, and disposal site selection are important health considerations because they all contain disease transmission routes. A thorough discussion of the health hazards associated with household wastes appears in Section 4.4. Vectors can also be disease carriers; their role is discussed in Section 4.3.

## 9.6 MANAGEMENT BY LOCAL AGENCIES

Generally, public health officials desire a third party to regulate and maintain alternative systems in order to provide assurances of high construction and maintenance quality. Individual wastewater systems lend themselves to regulation at three periods during their existence: siting, operation, and failure. The necessary legal authorities required to carry out these functions are as follows: the entity would need the authority to tax, charge, and collect service fees; the right of entry and the authority to perform maintenance and make repairs and replacements without approval of the property owner; and the authority to permit and regulate the construction of on-site systems. A recommended surveillance program for individual on-site systems should include the following techniques:

**Siting**—An initial review of the design and of the site before construction will help insure potential problems, due to siting or to design, are avoided. This is normally part of the permit process. This is also a good time to implement the user education program.

**Operation**—Periodic inspections should insure sound maintenance practices since potential problems can be identified early and remedied before major problems develop. General areas of observation should include but not be limited to the following. Is the unit adequate for the number of users and the frequency of use? Does visual inspection show evidence of vector, odor, liquid accumulation or surface or groundwater inundation problems? Are the screens, seals and vents adequate? Is specially marked handling equipment available and is the disposal location and method acceptable? A model inspection for covering these areas is shown on Table 9.1.

The recommended frequency of surveillance is site specific. Depending on rate of use, the small units may require more frequent inspection since the composting pile is within the residence. All units require frequent turning which may require that the user demonstrate an ability to properly maintain the system. Once this has been ascertained, the frequency of surveillance can be reduced. In the event a system is transferred to a new user such as with a rental or sale situation, the frequency of inspection should be increased until the regulatory agency is satisfied that proper procedures are being followed.

**Failure**—System failures may be due to difficulties maintaining the composting process and/or to defects with mechanical or physical parts of the unit itself. If the user is unwilling or unable to correct the problem, the regulatory agency should take whatever steps are necessary to prevent public health hazards from spreading.

## TABLE 9.10

## *RECOMMENDED*
## ALTERNATIVE SYSTEM INSPECTION FORM

### SYSTEM INFORMATION

Name

Address | City | State | Zip Code

Census Tract Number | Parcel Number | Telephone Number

### TYPE OF SYSTEM

☐ Small Vault Proprietary
☐ Large Vault Proprietary
☐ Grey Water
☐ Owner-Built Vault
☐ Owner-Built Drum
☐ Other ______________________

### GENERAL CHECKLIST

Number of Current Users __________________
Specially Marked Handling Equipment Available ☐ Yes ☐ No
Liquid Buildup ☐ Yes ☐ No
Evidence of Leaks or Overflows ☐ Yes ☐ No
Surface or Groundwater Inundation Problems ☐ Yes ☐ No
Urine Separation ☐ Yes ☐ No
Proper Handling ☐ Yes ☐ No
Proper Disposal ☐ Yes ☐ No
Toilet Seat Properly Sealed ☐ Yes ☐ No
All Vents Screened with 24 Mesh or Smaller ☐ Yes ☐ No
Odors ☐ Yes ☐ No
Vectors ☐ Yes ☐ No
Adequate Volume Remaining ☐ Yes ☐ No
Ventilation Adequate ☐ Yes ☐ No
Surfacing Water ☐ Yes ☐ No

### COUNTY REGULATIONS

Compliance with County's Regulations ☐ Yes ☐ No
Comments:

### GENERAL CONDITION

☐ Satisfactory ☐ Unsatisfactory ☐ Needs Follow-up Inspection

Comments:

______________________________, R. S. ______________________
District Sanitarian Date

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## SITE DESCRIPTION AND DATA

## UNIT A

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | < 10 feet |
| Soil Percolation: | < 45 min./in. |
| Depth to Bedrock: | 10 feet or greater |
| Slope: | 10 percent |
| Lot Size: | .58 acres |
| Other: | Located in basement of two-story home; hard to service due to location beneath house |

### UNIT DESIGN

| | |
|---|---|
| Type: | Large sloped fiberglass toilet, Clivus Multrum |
| Ventilation: | • 6" aluminum pipe extending 20' through roof<br>• Electric fan in pipe<br>• Wind vent at top<br>• Foam insulation on vent pipe |
| Other: | • Unit insulated with 1" foam<br>• Pest strip in composting chamber<br>• Seal on toilet seat<br>• Screens on vault and vent pipe<br>• Long excrement chute (approximately 12') from second floor<br>• Garbage chute from first floor with vertical port opening and elbow<br>• Rot-out plywood baffle between finished and fresh compost |

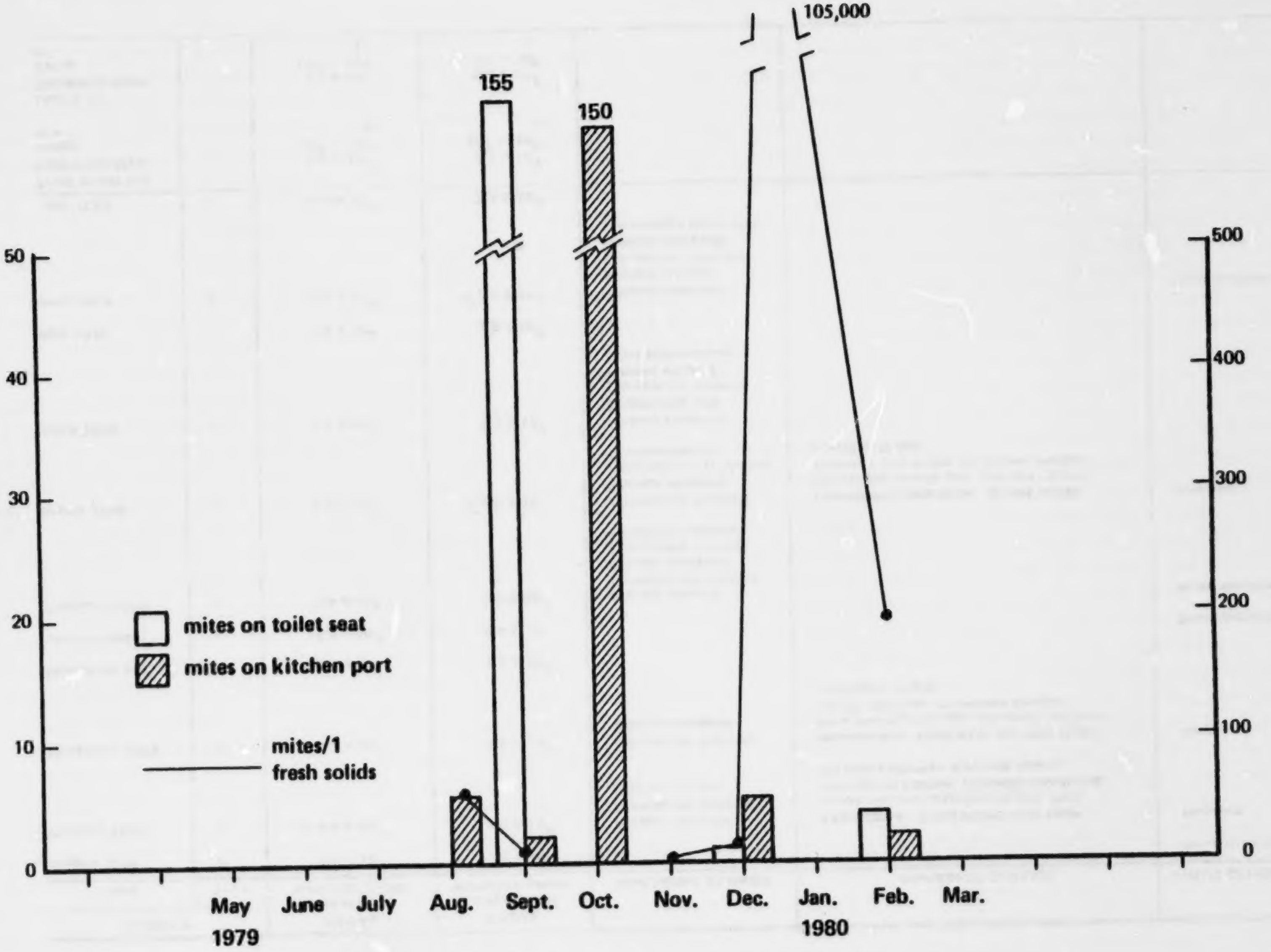
### UNIT HISTORY

Installed in April 1979, the unit has had two adult users; beginning in August 1979, a baby's disposable diapers were added to the unit. Additional users were infrequent. The users' diets were omnivorous. The unit was started up with commercial redwood compost. Kitchen wastes were added daily and ashes were added monthly.

### OBSERVATIONS

The unit was installed near the groundwater table level resulting in storage chamber flooding during the wet months (November—March). Nonetheless, the users reported no odor or liquid buildup problems. To help break up the pile, the owner pushed the material down the unit's slope when the pile became too high.

The fly tape data for this unit is presented as a narrative because it was very difficult to attach the tape inside the vault, and nine of the 14 tapes hung from May 1979 through June 1980 fell in or were damaged and counts could not be made. However, in most cases, presence or absence of a kind was able to be noted. The data showed that gnats were present in numbers of 100 to 600 in June through November 1979 but absent after January 1980. Small flies were present throughout the sampling period in numbers of 10 to 400. *Drosophila* appeared from September 1979 through January 1980 resulting in a fly problem in the home. An insecticide strip was hung in the unit in January, after which no *Drosophila* were found. In June and July, 1979 *Fannia* reached numbers of 100 per tape, but disappeared by November. A few *Ophyra* were found in June 1979 and two *Muscina* in October. This unit also had an infestation of blow flies (Calliphoridae) beginning in June, and 75 were found in July 1979.



GRAPH 1 UNIT A: OCCURRENCE OF MITES

### TABLE 1 UNIT A: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | $1.7 \times 10^8$ | $2.2 \times 10^7$ | | | None isolated |
| October 1979 | F | $>2.4 \times 10^9$ | $7.9 \times 10^8$ | Proteus mirabilis<br>Providencia stuartii<br>Proteus rettgeri | Appearance: Feces mixed with table scraps, fat, and artichoke leaves. Rare mite egg and larvae, probably free-living. No known human parasites found. | Reovirus |
| November 1979 | F | $1.7 \times 10^9$ | $4.6 \times 10^7$ | Citrobacter freundii<br>Proteus morganii | Appearance: Appears to be fresh feces. Few thin shelled eggs, too small for hookworm. Mite egg. No known human pathogens found. | Reovirus |
| November 1979 | L | $1.4 \times 10^6$ | $4.9 \times 10^2$ | | | |
| January 1980 | L | $3.3 \times 10^3$ | $2.0 \times 10$ | | | None isolated |
| February 1980 | L | $7.9 \times 10^4$ | $2.0 \times 10^2$ | Proteus vulgaris<br>Enterobacter cloacae<br>Proteus morganii<br>Citrobacter freundii<br>Klebsiella ozaenae | | None isolated |
| March 1980 | L | $2.2 \times 10^4$ | $<2.0 \times 10$ | Citrobacter freundii<br>Proteus morganii<br>Aeromonas hydrophila<br>Escherichia coli | Leachate—Appearance: Brown liquid. Occasional ciliates and cyst-like objects probably free-living. No known human parasites found. | Reovirus |
| April 1980 | L | $1.7 \times 10^5$ | $4.9 \times 10^3$ | Proteus mirabilis<br>Escherichia coli<br>Citrobacter freundii<br>Proteus vulgaris<br>Klebsiella ozaenae | | |
| May 1980 | L | $7.9 \times 10^5$ | $1.2 \times 10^4$ | | | |
| June 1980 | C | $2.2 \times 10^6$ | $<2.0 \times 10^2$ | Proteus mirabilis<br>Proteus vulgaris<br>Citrobacter freundii<br>Proteus morganii<br>Aeromonas hydrophila | | None isolated |
| June 1980 | L | $2.3 \times 10^5$ | $3.3 \times 10^3$ | | | |
| **Fresh Solids (F)** | | | | | | |
| Geometric Mean | | $8.9 \times 10^8$ | $9.3 \times 10^7$ | | | |
| Range | | $10^8 - 10^9$ | $10^7 - 10^8$ | | | |
| N = | | 3 | 3 | | | |
| **Liquid (L)** | | | | | | |
| Geometric Mean | | $1.1 \times 10^5$ | $5.0 \times 10^2$ | | | |
| Range | | $10^3 - 10^6$ | $10 - 10^4$ | | | |
| N = | | 7 | 7 | | | |

## TABLE 2 UNIT A: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | 7.6 | 80 | 21 | 80 | 20 |
| October 1979 | F | 6.0 | 75 | 25 | 85 | 15 |
| November 1979 | F | 7.7 | 71 | 29 | 44 | 56 |
| June 1980 | C | 5.9 | 78 | 22 | 85 | 15 |
| **Fresh Solids (F)** | | | | | | |
| Geometric Mean | | 7.1 | 75 | 25 | 67 | – |
| Range | | 6.0 – 7.7 | 71 – 80 | 21 – 29 | 44 – 85 | – |
| N = | | 3 | 3 | 3 | 3 | – |

## TABLE 3 UNIT A: LIQUID DATA

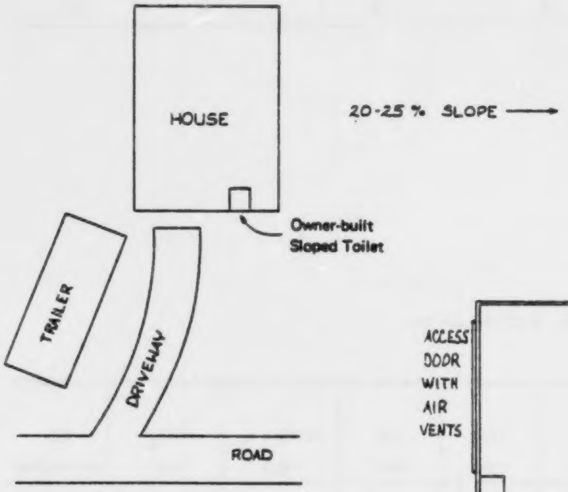
| SAMPLE | | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC μmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| November 1979 | L | 8.0 | – | 320 | 750 | $1.7 \times 10^3$ | 120 | 220 | 250 | $4.2 \times 10^3$ |
| January 1980 | L | 7.3 | 15 | LE | 60 | 740 | 40 | 10 | 250 | $1.4 \times 10^3$ |
| February 1980 | L | 7.4 | 4.1 | LE | 730 | $3.2 \times 10^3$ | 180 | 360 | $1.0 \times 10^3$ | $4.4 \times 10^3$ |
| March 1980 | L | 7.3 | 2.0 | LE | $1.1 \times 10^3$ | $4.8 \times 10^3$ | 50 | 60 | $1.7 \times 10^3$ | $7.6 \times 10^3$ |
| April 1980 | L | 7.2 | 4.8 | LE | 980 | $5.6 \times 10^3$ | 30 | 540 | $2.1 \times 10^3$ | $7.7 \times 10^3$ |
| **Liquid (L)** | | | | | | | | | | |
| Geometric Mean | | 7.4 | 5.8 | LE | 513 | $2.6 \times 10^3$ | 145 | 120 | 750 | $4.3 \times 10^3$ |
| Range | | 7.2 – 8.0 | 4.1 – 15 | – | $10 – 10^3$ | $10 – 10^3$ | 30 – 180 | 10 – 540 | $10^2 – 10^3$ | $10^3$ |
| N = | | 5 | 5 | – | 5 | 5 | 5 | 5 | 5 | 5 |

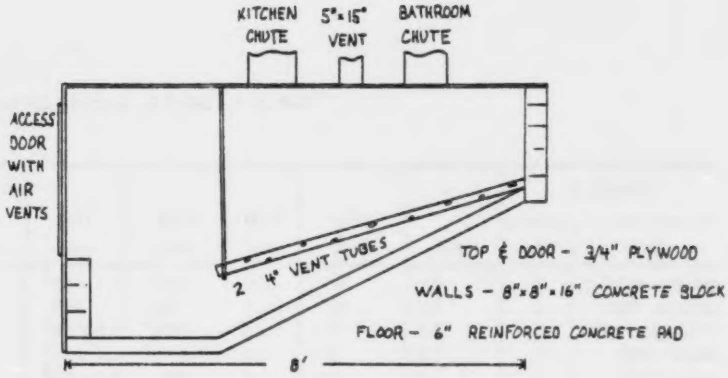
LE = Laboratory Error

## UNIT B

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 25'–30' |
| Soil Percolation: | <45 min./in. |
| Depth to Bedrock: | 10 feet |
| Drinking Water Source: | Spring |
| Slope: | 20–25 percent |
| Lot Size: | 1½ acres |
| Other: | Unit located beneath house |


HOUSE
20-25 % SLOPE
Owner-built Sloped Toilet
TRAILER
DRIVEWAY
ROAD


KITCHEN CHUTE
5"x15" VENT
BATHROOM CHUTE
ACCESS DOOR WITH AIR VENTS
2 4" VENT TUBES
TOP & DOOR - 3/4" PLYWOOD
WALLS - 8"x8"x16" CONCRETE BLOCK
FLOOR - 6" REINFORCED CONCRETE PAD
8'

### UNIT DESIGN

| | |
|---|---|
| Type: | Owner-built sloped toilet |
| Size: | 4' x 5' x 8' |
| Construction Material: | • Reinforced concrete pad floor<br>• 6" thick cinder block vault walls (8' x 8' x 16')<br>• 3/4" plywood floor and door |
| Ventilation: | • 5½" x 15½" main vent stack<br>• 2"–3" perforated pipes inside chamber<br>• 5" x 10" mesh screen on entry door |
| Other: | • No additional insulation<br>• Vented access door to unit<br>• Screened vent pipe |

## SERVICE HISTORY

Installed in April 1979, this large owner-built sloped toilet accommodated three full-time users with occasional guests. Users and visitors were vegetarian.

The unit was started up with grass clippings, soil, and peat moss packed on the slant and floor of the finished compost chamber. After each use one or two handfuls of sawdust were added. Kitchen wastes were also added daily and grass clippings every month or so through the toilet port since the kitchen port was never finished off in the kitchen. The pile was never mixed and the composted contents have not been removed yet.

## OBSERVATIONS

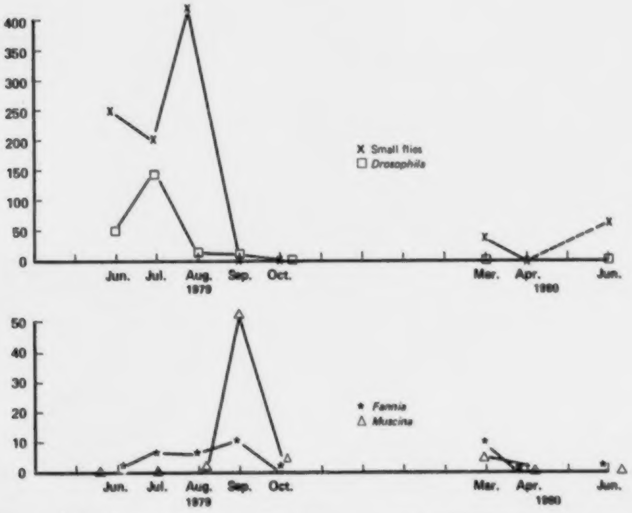
The owners reported black beetles, "household" flies and fruit flies after the addition of kitchen wastes and green grass clippings. They hung a fly strip in the bathroom which did not control the insect problem.

Liquid buildup and odors were not reported as problems by the owners although sulfide odors were reported by the sampler. The owners were very responsible in maintaining the unit but lacked sufficient information about the composting process.

Very few mites were taken on the swabs from this unit (one in August 1979 and two in June 1980 from the kitchen port, and four in September 1979 and eight in June 1980 from the toilet seat).

To simplify the fly tape graphs, the gnats are reported in tabular form below:

| | 1979 | | | | | 1980 | | |
|---|---|---|---|---|---|---|---|---|
| | June | July | August | September | October | March | April | June |
| Number of gnats counted | 2,000 | 1,200 | 1,400 | 3,100 | 600 | 2,000 | 25 | 60 |



GRAPH 1 UNIT B: OCCURRENCE OF FLYING INSECTS

### TABLE 1 UNIT B: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | F | $2.8 \times 10^6$ | $1.3 \times 10^6$ | | | | |
| Site unused between December through late April 1980. | | | | | | | |
| March 1980 | C | $1.4 \times 10^7$ | $2.2 \times 10^8$ | | | | 4 months storage |
| March 1980 | C | $2.3 \times 10^5$ | $2.3 \times 10^5$ | | | | 10 months storage |
| April 1980 | C | $7.9 \times 10^8$ | $1.3 \times 10^5$ | | | | 5 months storage |
| April 1980 | C | $7.9 \times 10^7$ | $7.9 \times 10^7$ | | | | 11 months storage |
| May 1980 | C | $3.3 \times 10^5$ | $8.0 \times 10^2$ | Citrobacter freundii<br>Escherichia coli<br>Klebsiella oxytoca<br>Enterobacter cloacae<br>Pseudomonas cepacia<br>Providencia rettgeri | Finished Compost—Appearance: Finished compost. Occasional larvae, probably free-living. No known human parasites found. | | |
| June 1980 | C | $4.9 \times 10^6$ | $1.1 \times 10^6$ | | | | |
| **Finished (C)** | | | | | | | |
| Geometric Mean | | $5.7 \times 10^6$ | $6.0 \times 10^5$ | | | | |
| Range | | $10^5 - 10^7$ | $10^2 - 10^7$ | | | | |
| N = | | 6 | 6 | | | | |

### TABLE 2 UNIT B: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | 8.2 | 62 | 38 | 84 | 16 |
| March 1980 | C | 6.3 | 58 | 42 | 82 | 18 |
| March 1980 | C | 7.3 | 72 | 28 | 61 | 39 |
| April 1980 | C | 6.9 | 71 | 29 | 80 | 20 |
| April 1980 | C | 7.5 | 36 | 64 | 16 | 84 |
| May 1980 | C | 7.5 | 49 | 51 | 66 | 34 |
| June 1980 | C | 7.2 | 32 | 68 | 11 | 89 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 7.1 | 50 | 44 | 41 | 39 |
| Range | | 6.9 – 7.5 | 36 – 72 | 28 – 68 | 11 – 82 | 18 – 89 |
| N = | | 6 | 6 | 6 | 6 | 6 |

## UNIT C

### SITE DESCRIPTION

Climate: Coastal
Depth to Groundwater: N. A. < 4 feet
Soil Percolation: < 45 min./in.
Depth to Bedrock: > 10 feet
Drinking Water Source: Public water supply
Slope: 10 percent
Lot Size: 6/10 acre
Other: Installed in guest house

### UNIT DESIGN

Type: Large, sloped-fiberglass toilet, Clivus Multrum
Ventilation: Vent through roof; turbine fan
Other: Extra midsection; no insulation

### SERVICE HISTORY

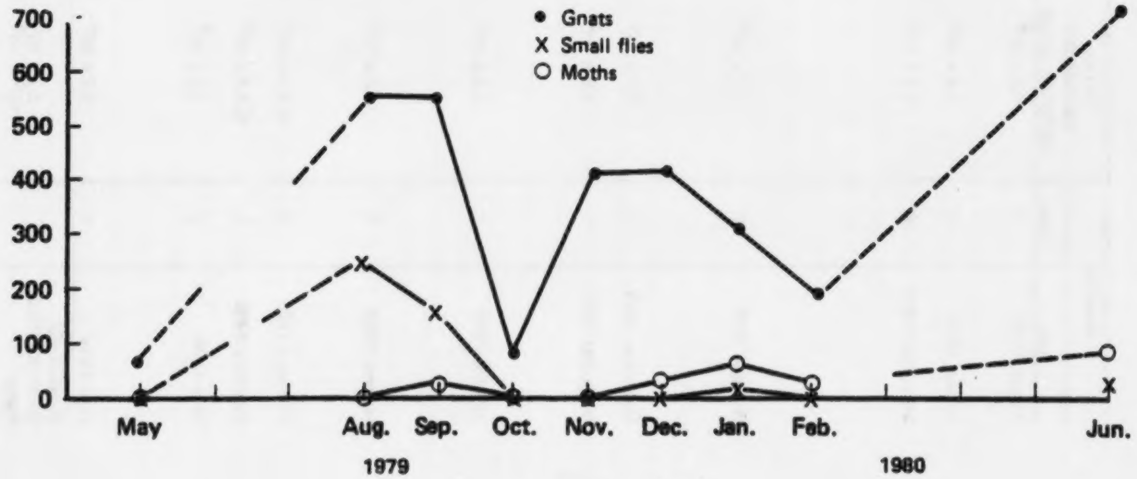
Installed in February 1979, this unit in the guest house served varied number of guests ranging from one person full-time to occasional guests (4) to large gatherings of people.

The unit was started with soil, pine sawdust, leaf mold and goat droppings. The owner then added tree leaves and grass clippings to the pile on a regular basis. Spiders were introduced via leaf mold into the unit. The owner discontinued using the unit from February to April, except for irregular use (once/week). Beginning in April one person used the unit full-time.

### OBSERVATIONS

The contents have never been mixed or turned.

No domestic flies were taken from this unit, and no mites were found on the seat and kitchen port swabs.



GRAPH 1 UNIT C: OCCURRENCE OF FLYING INSECTS

## TABLE 1 UNIT C: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | $4.6 \times 10^8$ | $2.2 \times 10^8$ | Citrobacter freundii<br>Escherichia coli | Appearance: Looks like fresh feces. No parasites found. | None Isolated |
| August 1979 | C | $7.9 \times 10^5$ | $8.0 \times 10^3$ | | | |
| September 1979 | F | $1.1 \times 10^7$ | $3.3 \times 10^6$ | Proteus vulgaris<br>Enterobacter cloacae<br>Proteus rettgeri | Appearance: Appears to be fresh feces, one human Trichuris trichiura egg seen—viability studies in progress. Also a few thin-shelled eggs and larvae, not human pathogens. Viability on *Trichuris trichiura.* Only two eggs found—do not appear to be viable after six weeks observation. | None Isolated |
| October 1979 | F | $1.7 \times 10^8$ | $2.8 \times 10^6$ | Citrobacter freundii<br>Providencia rettgeri<br>Proteus vulgaris<br>Klebsiella oxytoca | Appears to be fresh feces. Eggs resembling hookworm but too small, rare degenerate larva seen. No known human parasites found. | None Isolated |
| November 1979 | L | $1.1 \times 10^4$ | $4.0 \times 10$ | | | |
| December 1979 | L | $4.9 \times 10^2$ | $2.0 \times 10$ | Proteus morganii<br>Citrobacter freundii<br>Escherichia coli<br>Proteus vulgaris | Leachate—Appearance: Brown liquid. Live ciliates, not human pathogens. No known human parasites found. | None Isolated |
| January 1980 | C | $7.9 \times 10^5$ | $2.3 \times 10^3$ | | Finished Compost—Appearance: Looks like muddy feces. Few eggs, occasional larva, probably free-living. No known human parasites found. | |
| January 1980 | L | $3.3 \times 10^3$ | $<2.0 \times 10$ | | Leachate—Appearance: Yellow clear liquid. Few live ciliates. No known human parasites found. | |
| February 1980 | C | $\geq 2.4 \times 10^9$ | $2.4 \times 10^9$ | | | |
| February 1980 | L | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | |
| June 1980 | C | $3.3 \times 10^4$ | $2.0 \times 10^2$ | Proteus morganii<br>Proteus mirabilis<br>Citrobacter freundii<br>Escherichia coli | Finished Compost—Appearance: Looks like mud. Occasional larvae, probably free-living. No known human parasites found. | |
| June 1980 | L | $4.9 \times 10^4$ | $<2.0 \times 10$ | | | |
| Finished (C)<br>Geometric Mean<br>Range<br>N = | | <br>$2.7 \times 10^5$<br>$10^4 - 10^5$<br>3 | <br>$5.5 \times 10^4$<br>$10^2 - 10^9$<br>4 | | | |

## TABLE 2 UNIT C: SOLID DATA

| SAMPLE |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| Date | Type | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
| August 1979 | F | 8.2 | 70 | 30 | 53 | 47 |
| August 1979 | C | 7.5 | 28 | 72 | 14 | 86 |
| September 1979 | F | 8.2 | 31 | 69 | 9 | 91 |
| October 1979 | F | 7.3 | 49 | 51 | 20 | 80 |
| January 1980 | C | 5.0 | 36 | 64 | 13 | 87 |
| February 1980 | C | 6.7 | 41 | 59 | 15 | 85 |
| June 1980 | C | 6.4 | 44 | 56 | 12 | 88 |
| Finished (C) |  |  |  |  |  |  |
| Geometric Mean |  | 6.3 | 37 | 62 | 13 | 86 |
| Range |  | 5.0 – 7.5 | 28 – 44 | 56 – 72 | 12 – 15 | 85 – 88 |
| N = |  | 4 | 4 | 4 | 4 | 4 |

## TABLE 3 UNIT C: LIQUID DATA

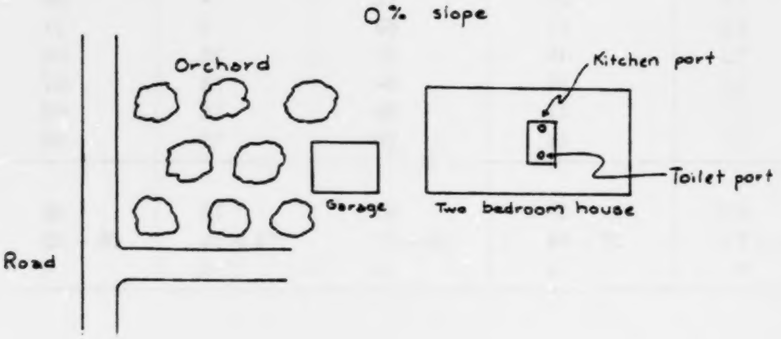
| SAMPLE |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
| November 1979 | L | 6.8 | LE | $1.4 \times 10^3$ | $2.5 \times 10^4$ | $1.2 \times 10^3$ | 360 | – | $1.1 \times 10^4$ | $4.0 \times 10^4$ |
| December 1979 | L | 6.9 | LE | $1.2 \times 10^3$ | $2.7 \times 10^4$ | 190 | 420 | 37 | $1.2 \times 10^4$ | $2.8 \times 10^4$ |
| January 1980 | L | 6.3 | LE | $1.1 \times 10^3$ | $2.7 \times 10^4$ | 150 | 60 | 150 | $1.3 \times 10^4$ | $2.8 \times 10^4$ |
| February 1980 | L | 6.8 | LE | $1.1 \times 10^3$ | $2.7 \times 10^4$ | 290 | 70 | 69 | $1.1 \times 10^4$ | $1.7 \times 10^4$ |
| Liquid (L) |  |  |  |  |  |  |  |  |  |  |
| Geometric Mean |  | 6.7 | LE | $1.2 \times 10^3$ | $2.6 \times 10^4$ | $1.1 \times 10^3$ | 158 | 73 | $1.2 \times 10^4$ | $2.7 \times 10^4$ |
| Range |  | 6.3 – 6.9 | LE | $10^3$ | $10^4$ | $10^2 - 10^3$ | 60 – 420 | 37 – 150 | $10^4$ | $10^4$ |
| N = |  | 4 | LE | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

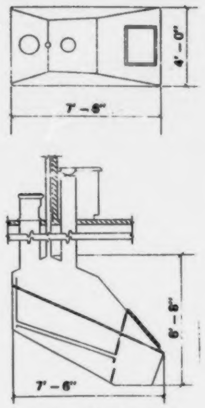
LE = Laboratory Error

# UNIT D

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 108 feet |
| Soil Percolation: | 45–60 min./in. |
| Depth to Bedrock: | > 4 feet |
| Slope: | 0 percent |
| Lot Size: | 2.5 acres |
| Other: | Cement slab floor and cement block walls in basement of house |





Large Sloped Fiberglas Toilet

## UNIT DESIGN

Type: Large, sloped fiberglas toilet—older model, Clivus Multrum

Other:
- Screened vent pipe
- Sealed toilet seat
- No baffle between storage and finish chamber
- 12-watt vent fan

## SERVICE HISTORY

Installed in March 1977, the unit accommodated four users full-time (two adults and two children) with occasional visitor use. The family's diet was mixed, with some meat. The toilet seat was kept closed when not in use.

The owners started the unit by placing two feet of peat moss and oak leaf mold on the sloping floor. Kitchen and garden wastes were added daily and a bucket of sawdust was added every four to six weeks. The fan was used continuously except when the family vacationed (one week/four months). The users occasionally "raked down the piles." In April 1979, the finished chamber was emptied with an unmarked large shovel and bucket; the composted contents (15 gallons "wet solids" and 5 gallons leachate) were added to yard waste (grass clippings, orchard trimmings) compost piles and will be used in the orchard this fall.

## HIGHLIGHTS

During start-up, a lot of material slid down to the finish chamber which may have improved air circulation and liquid absorption. The unit had little liquid buildup and the owner used what liquid there was for watering ornamental plants. The owners had originally added garden refuse to their system but noticed that this formed hard piles which did not compost or slide to the chamber bottom. The owners currently add sawdust to their system.

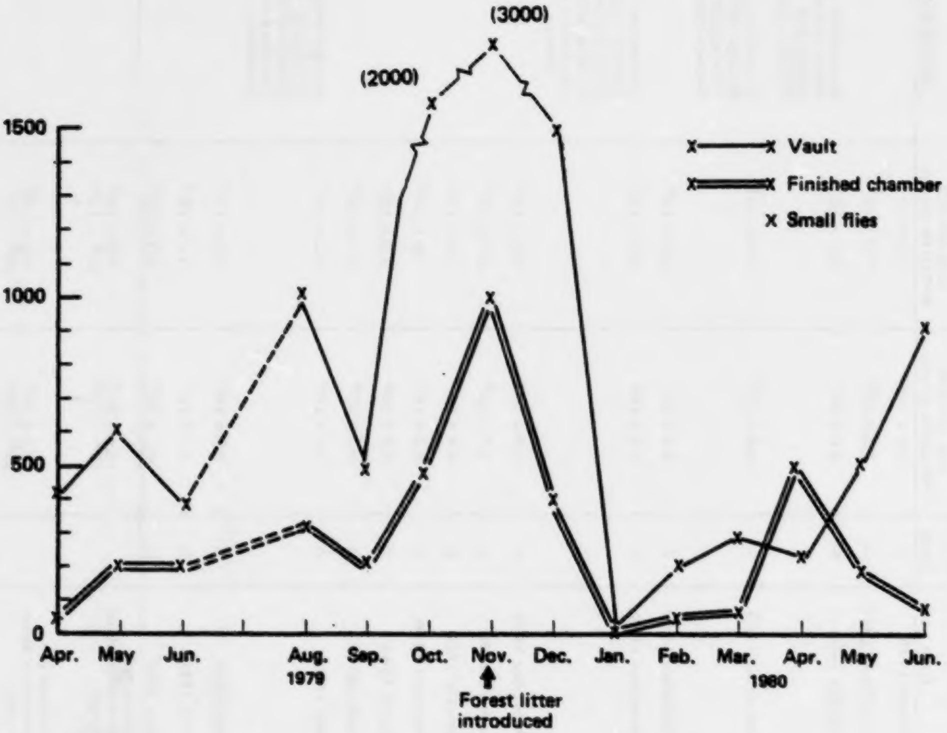
The addition of kitchen wastes was associated with insect problems, especially in the summer when small flies and beetles (Nitidulids) emerged into the kitchen and spider webs interfered with the vent's circulation. The owner sprayed with an insecticide and hung a pest strip in the composting chamber. This control effort was moderately effective. The users did not consider odors to be a problem.

## TABLE 1 UNIT D: MICROBIOLOGICAL DATA

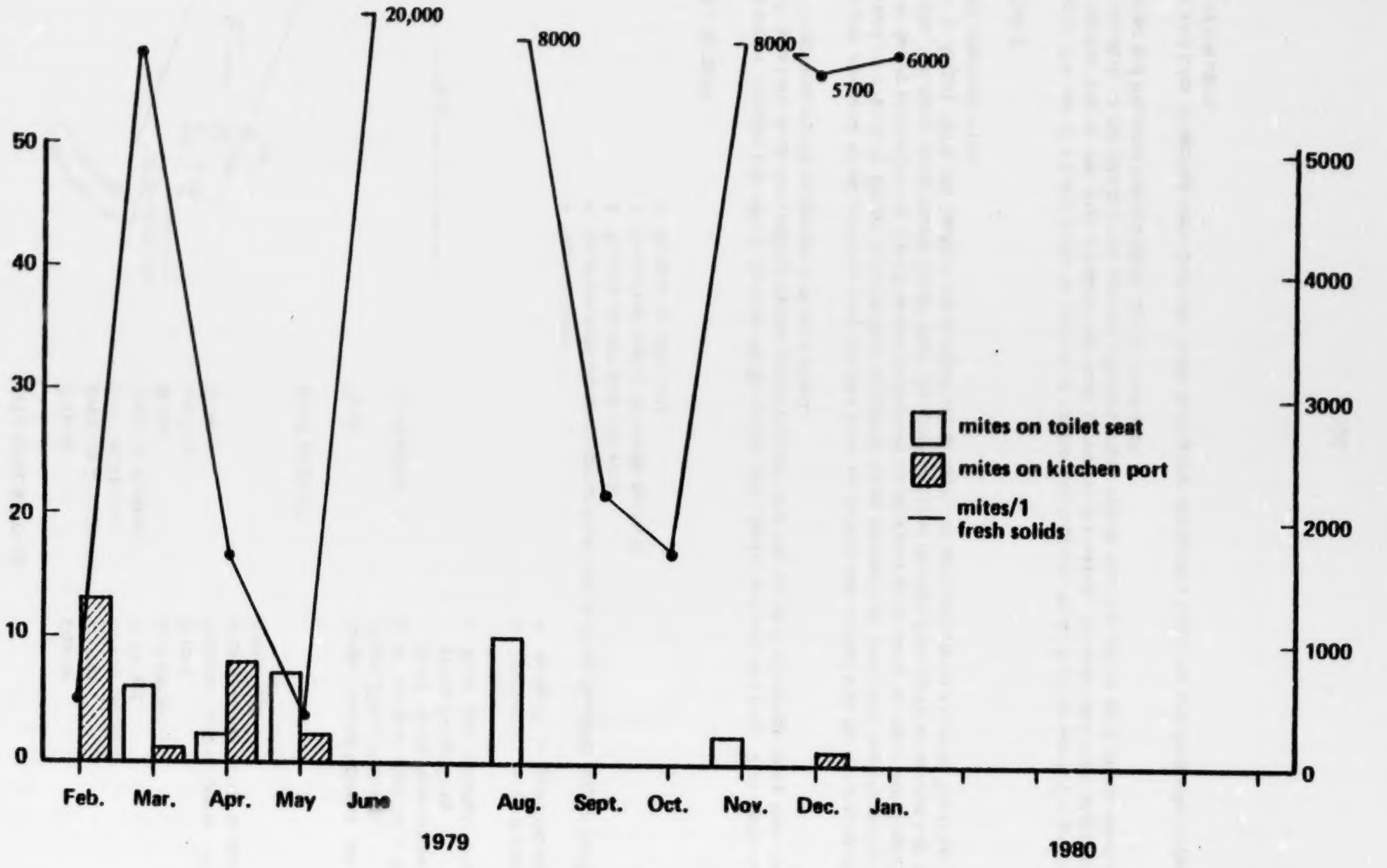
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | $2.8 \times 10^6$ | $3.3 \times 10^3$ | | | |
| September 1979 | C | $7.9 \times 10^5$ | $4.9 \times 10^5$ | | | |
| October 1979 | M | $3.5 \times 10^9$ | $4.9 \times 10^7$ | Escherichia coli<br>Enterobacter cloacae<br>Citrobacter freundii<br>Proteus rettgeri | Appears to be dry compost with dry feces. Mite eggs, larvae, probably free-living. No known human parasites found. | None Isolated |
| November 1979 | F | $1.6 \times 10^{10}$ | $3.3 \times 10^8$ | Escherichia coli<br>Proteus rettgeri<br>Enterobacter sakazakii<br>Proteus mirabilis | Appearance: Finished compost with piece of dried feces and vegetable leaves. Degenerate larvae, probably free-living. No known human pathogens found. | None Isolated |
| November 1979 | C | $3.3 \times 10^7$ | $2.2 \times 10^6$ | | | |
| December 1979 | F | $4.9 \times 10^8$ | $4.9 \times 10^8$ | Citrobacter freundii<br>Proteus vulgaris<br>Enterobacter cloacae<br>Serratia rubidaea<br>Citrobacter diversus-levinca | Fresh Compost with Sawdust—Appearance: Appears to be finished compost. Few live and dead larvae, probably free-living. Occasional small thin-shelled egg. No human parasites found. | None Isolated |
| December 1979 | C | $4.9 \times 10^4$ | $4.9 \times 10^3$ | | | |
| January 1980 | L | $1.3 \times 10^4$ | $3.4 \times 10^2$ | | | |
| January 1980 | C | $4.9 \times 10$ | $7.0 \times 10^5$ | | | |
| February 1980 | C | $2.3 \times 10^4$ | $7.9 \times 10^3$ | | | |
| March 1980 | C | $4.9 \times 10^8$ | $7.0 \times 10^6$ | | | |
| April 1980 | C | $2.3 \times 10^6$ | $1.7 \times 10^4$ | | | |
| May 1980 | C | $1.1 \times 10^6$ | $2.3 \times 10^4$ | Proteus vulgaris<br>Citrobacter freundii<br>Enterobacter cloacae<br>Yersinia enterocolitica<br>Providencia rettgeri | Finished Compost—Appearance: Finished compost. Few larvae, probably free-living, occasional mite egg. No known human parasites found. | |
| May 1980 | L | $7.9 \times 10^6$ | $1.3 \times 10^3$ | | | |
| June 1980 | C | $1.1 \times 10^7$ | $1.3 \times 10^3$ | | | |
| June 1980 | L | $4.9 \times 10^4$ | $1.3 \times 10^4$ | | | |
| Liquid (L)<br>Geometric Mean<br>Range<br>N = | | <br>$2.5 \times 10^5$<br>$10^4 - 10^6$<br>4 | <br>$7.3 \times 10^3$<br>$10^2 - 10^5$<br>4 | | | |
| Finished (C)<br>Geometric Mean<br>Range<br>N = | | <br>$2.4 \times 10^6$<br>$10^4 - 10^8$<br>10 | <br>$5.7 \times 10^4$<br>$10^3 - 10^6$<br>10 | | | |

## TABLE 2 UNIT D: SOLID DATA

| SAMPLE | | | | | | |
|---|---|---|---|---|---|---|
| Date | Type | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
| August 1979 | C | 6.0 | 44 | 56 | 42 | 58 |
| August 1979 | C | 7.1 | 39 | 61 | 43 | 57 |
| October 1979 | C | 6.1 | 66 | 34 | 85 | 15 |
| November 1979 | F | 5.6 | 58 | 42 | 38 | 62 |
| November 1979 | C | 6.5 | 19 | 81 | 58 | 42 |
| December 1979 | C | 5.8 | 61 | 39 | 58 | 42 |
| December 1979 | F | 7.6 | 59 | 41 | 76 | 24 |
| January 1980 | C | 7.9 | 33 | 68 | 48 | 52 |
| February 1980 | C | 7.3 | 62 | 38 | 67 | 33 |
| March 1980 | C | 6.8 | 55 | 45 | 76 | 24 |
| April 1980 | C | 5.9 | 50 | 50 | 69 | 31 |
| May 1980 | C | 5.6 | 63 | 37 | 58 | 42 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 6.4 | 46 | 49 | 39 | 37 |
| Range | | 5.6 – 7.9 | 19 – 66 | 37 – 68 | 42 – 85 | 15 – 52 |
| N = | | 10 | 10 | 10 | 10 | 10 |

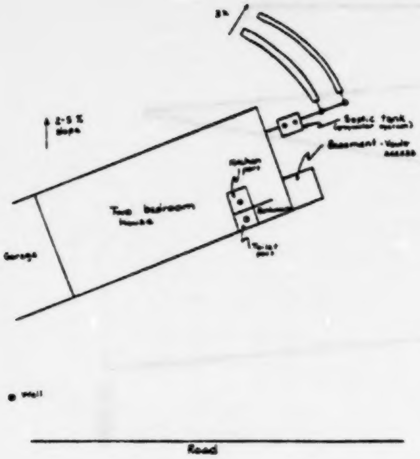


GRAPH 1 OCCURRENCE OF FLYING INSECTS



GRAPH 2 OCCURRENCE OF MITES

## UNIT E



### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 25 feet |
| Soil Percolation: | 40–60 min./in. |
| Depth to Bedrock: | > 75 feet |
| Slope: | 2–5 percent |
| Lot Size: | ½ acre |
| Other: | Installed below corner of house with chamber access through basement. |

### UNIT DESIGN

| | |
|---|---|
| Type: | Large, sloped-fiberglas toilet, old model, Clivus Multrum |
| Ventilation: | • 4" exhaust duct to a 6" insulated pipe approximately 5' above the roof line<br>• Vent top covered with wind turbine<br>• Exhaust fan (squirrel cage fan)<br>• No baffle between chambers |

Other:

- No insulation
- Leachate recirculation pump and sprinkler nozzles (installed August 1979)
- Screens on vent pipe and vault
- Unmarked bucket to handle contents
- No seal on toilet seat

### SERVICE HISTORY

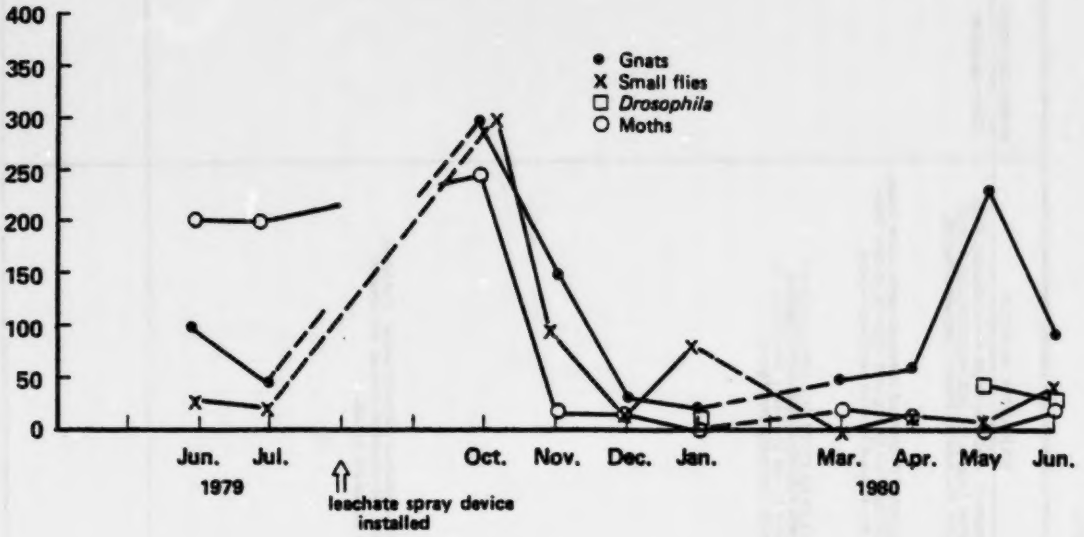
The owner installed this unit in October 1976 starting with a bed of soil and peat moss. Two adults have used it on a full-time basis since then, adding kitchen wastes regularly and two handfuls of sawdust every two—four days. The users' diets were mainly vegetarian with some meats.

The pile was never mixed; contents were removed every six months and worked into the soil around trees. The owner turned on a fan daily (about 16 hours/day) to control odors, sprayed with insecticide (pyrethrum) as often as every other day to control insects (fruit flies and moths) and maintained a spray pump to redistribute liquid buildup over the pile. The sump pump moved liquid from the finish chamber through three sprinkler nozzles over the fresh pile. Prior to August 1979, the leachate was pumped out to water the lawn about once a month. The toilet seat was kept closed when not in use.

### HIGHLIGHTS

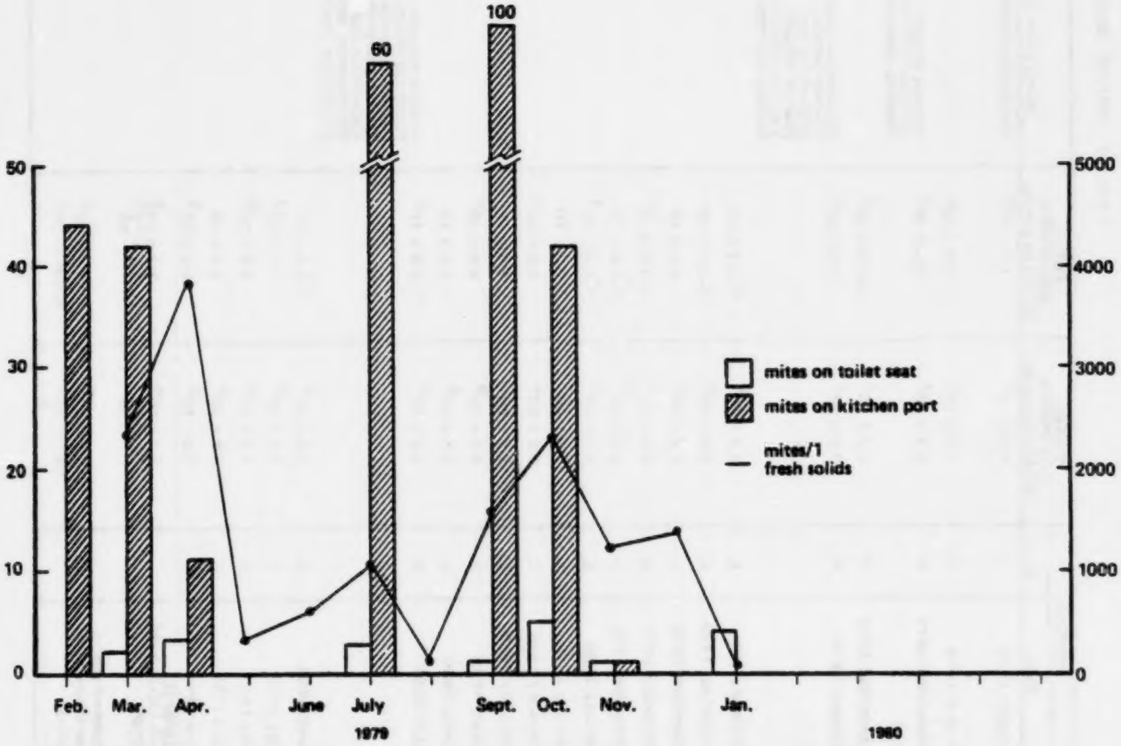
Despite the use of a sump pump to remove or redistribute leachate, liquid buildup was still a problem. The finished material was so wet that a bucket was used to remove the wastes. The users also tried adding more dry material (sawdust) to the pile but this was not effective. Water leaked into the unit in early March when the basement flooded and the sump pump clogged later in the month.

Rat and mice droppings were observed twice during the sanitarian's visits; no problems with rodents were reported by the users.



⇑ leachate spray device installed

GRAPH 1 UNIT E: OCCURRENCE OF FLYING INSECTS



GRAPH 2 UNIT E: OCCURRENCE OF MITES

## TABLE 1 UNIT E: MICROBIOLOGICAL DATA

| SAMPLE |  | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type |  |  |  |  |  |
| August 1979 | F | $4.9 \times 10^8$ | $1.3 \times 10^8$ | Citrobacter freundii | Appearance: Appears to be dry compost. Eggs and larvae found. Do not resemble any human pathogen. No known human parasites found. | None isolated |
| August 1979 | L | $1.1 \times 10^7$ | $7.9 \times 10^5$ |  |  |  |
| September 1979 | F | $1.7 \times 10^8$ | $7.9 \times 10^7$ | Proteus vulgaris<br>Citrobacter freundii<br>Yersinia enterocolitica | Appearance: Processed compost with some feces and insects. Few larvae and eggs—probably free-living. No known human parasites found. |  |
| September 1979 | C | $3.3 \times 10^4$ | $<2.0 \times 10^2$ |  |  |  |
| October 1979 | F | $3.5 \times 10^9$ | $7.0 \times 10^8$ | Citrobacter freundii<br>Proteus rettgeri<br>Escherichia coli<br>Proteus vulgaris<br>Yersinia enterocolitica<br>Proteus mirabilis | Appears to be moist processed compost. Mite eggs, cyst-like objects not human type, few larvae probably free-living. No known human parasites found. |  |
| October 1979 | L | $1.3 \times 10^4$ | $<2.0 \times 10$ |  |  |  |
| November 1979 | C | $2.3 \times 10^4$ | $<2.0 \times 10$ |  |  |  |
| November 1979 | L | $2.8 \times 10^3$ | $2.0 \times 10$ |  |  |  |
| December 1979 | C | $4.9 \times 10^4$ | $<2.0 \times 10^2$ |  |  |  |
| December 1979 | L | $4.9 \times 10^3$ | $<2.0 \times 10$ |  |  |  |
| January 1980 | C | $2.3 \times 10^3$ | $<2.0 \times 10^2$ |  |  |  |
| January 1980 | L | $8.0 \times 10$ | $<2.0 \times 10$ |  |  |  |
| February 1980 | C | $7.9 \times 10^4$ | $8.0 \times 10^2$ |  |  |  |
| February 1980 | L | $3.3 \times 10^3$ | $5.0 \times 10$ |  |  |  |
| March 1980 | C | $3.1 \times 10^8$ | $5.0 \times 10^2$ |  |  |  |
| March 1980 | L | $3.3 \times 10^4$ | $2.0 \times 10$ |  |  |  |
| April 1980 | C | $2.3 \times 10^6$ | $<2.0 \times 10^2$ | Proteus vulgaris<br>Klebsiella rhinoscleromatis<br>Proteus mirabilis<br>Proteus morganii<br>Escherichia coli<br>Enterobacter cloacae<br>Citrobacter freundii | Finished Compost—Appearance: Finished compost. No parasites found. No known human parasites found. |  |
| April 1980 | L | $1.3 \times 10^4$ | $<2.0 \times 10$ |  |  |  |
| May 1980 | C | $7.0 \times 10^4$ | $2.3 \times 10^3$ |  |  |  |
| May 1980 | L | $3.3 \times 10^5$ | $4.9 \times 10^3$ |  |  |  |
| June 1980 | L | $2.8 \times 10^4$ | $8.0 \times 10$ |  |  |  |
| June 1980 | C | $7.0 \times 10^6$ | $2.3 \times 10^4$ |  |  |  |
| Liquid (L) |  |  |  |  |  |  |
| Geometric Mean |  | $1.7 \times 10^4$ | $1.3 \times 10^2$ |  |  |  |
| Range |  | $10 - 10^7$ | $40 - 10^5$ |  |  |  |
| N = |  | 10 | 10 |  |  |  |
| Finished (C) |  |  |  |  |  |  |
| Geometric Mean |  | $2.4 \times 10^5$ | $5.7 \times 10^2$ |  |  |  |
| Range |  | $10^3 - 10^8$ | $<10^2 - 10^4$ |  |  |  |
| N = |  | 9 | 9 |  |  |  |

## TABLE 2 UNIT E: SOLID DATA

| SAMPLE |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| Date | Type | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
| August 1979 | F | 6.5 | 72 | 28 | 72 | 28 |
| September 1979 | C | 4.7 | 29 | 71 | 6 | 94 |
| September 1979 | F | 6.8 | 71 | 29 | 83 | 17 |
| October 1979 | F | 7.0 | 78 | 22 | 75 | 25 |
| November 1979 | C | 4.8 | 80 | 20 | 3 | 97 |
| December 1979 | C | 4.4 | 27 | 73 | 5 | 95 |
| January 1980 | C | 4.9 | 27 | 73 | 3 | 97 |
| February 1980 | C | 5.4 | 85 | 15 | 40 | 60 |
| March 1980 | C | 5.4 | 76 | 24 | 32 | 68 |
| April 1980 | C | 5.3 | 32 | 68 | 4 | 96 |
| May 1980 | C | 5.5 | 51 | 49 | 18 | 82 |
| **Finished (C)** |  |  |  |  |  |  |
| Geometric Mean |  | 5.0 | 45 | 42 | 8 |  |
| Range |  | 4.4 – 5.5 | 27 – 85 | 15 – 73 | 3 – 40 |  |
| N = |  | 8 | 8 | 8 | 8 |  |

## TABLE 3 UNIT E: LIQUID DATA

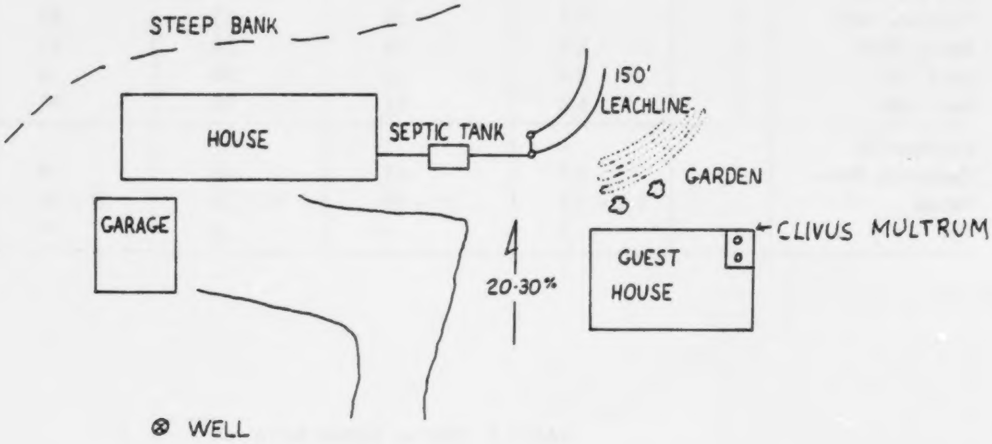
| SAMPLE |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC $\mu$mhos/cm |
| August 1979 | L | 6.5 | – | LE | $1.4 \times 10^3$ | $1.9 \times 10^4$ | 250 | $1.3 \times 10^3$ | 58.5 | $2.7 \times 10^4$ |
| September 1979 | L | 5.7 | – | LE | $1.3 \times 10^3$ | $2.7 \times 10^4$ | 20 | 390 | $9.1 \times 10^3$ | $2.3 \times 10^3$ |
| October 1979 | L | 5.8 | – | LE | $1.2 \times 10^3$ | $2.6 \times 10^4$ | 40 | 480 | $8.7 \times 10^3$ | $2.7 \times 10^4$ |
| November 1979 | L | 5.4 | – | LE | $1.2 \times 10^3$ | $2.3 \times 10^4$ | 60 | 610 | $1.0 \times 10^4$ | $2.8 \times 10^4$ |
| December 1979 | L | 5.3 | – | LE | $1.2 \times 10^3$ | $2.3 \times 10^4$ | 50 | 30 | $8.9 \times 10^3$ | $2.4 \times 10^4$ |
| January 1980 | L | 4.9 | – | LE | 980 | $2.1 \times 10^4$ | 40 | 590 | $1.1 \times 10^4$ | $2.4 \times 10^4$ |
| February 1980 | L | 4.6 | – | LE | $1.0 \times 10^3$ | $1.8 \times 10^4$ | 30 | 340 | $1.1 \times 10^4$ | $2.2 \times 10^4$ |
| March 1980 | L | 5.2 | 0.7 | LE | 240 | $1.8 \times 10^4$ | 60 | 750 | $8.9 \times 10^3$ | $2.6 \times 10^4$ |
| April 1980 | L | 5.4 | 0.5 | LE | 960 | $2.1 \times 10^4$ | 50 | 670 | $5.7 \times 10^3$ | $1.7 \times 10^4$ |
| **Liquid (L)** |  |  |  |  |  |  |  |  |  |  |
| Geometric Mean |  | 5.3 | – | LE | 962 | $2.2 \times 10^4$ | 51 | 425 | $3.3 \times 10^3$ | $1.9 \times 10^4$ |
| Range |  | 4.6 – 5.8 | – | LE | 240 – 1400 | $1.8 - 2.7 \times 10^4$ | 20 – 250 | $10 - 10^3$ | $3.3 \times 10^3$ | $10^3 - 10^4$ |
| N = |  | 9 | 2 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

LE = Laboratory Error

## UNIT F

### SITE DESCRIPTION

Climate: Coastal
Depth to Groundwater: 150 feet
Soil Percolation: 30 min./in.
Drinking Water Source: Well (see site drawing)
Slope: 20–30 percent
Lot Size: 1.02 acres
Other: Standard flush toilet/septic system located in nearby main house



### UNIT DESIGN

Type: Large, sloped-fiberglas toilet, Clivus Multrum
Ventilation: Standard 6" pipe with electric fan
Other:
- Storage end of unit exposed to afternoon sun
- Screened vault and vent pipe
- No insulation

### SERVICE HISTORY

Installed in November 1977 in a guest house, the unit was used by two regular users with infrequent visitors. The users' diets were omnivorous.

The unit was started up with garden soil, leaves, and peat moss. One pound of peat moss was added per week and kitchen wastes were added daily. Fecal matter occasionally extended into the chute and the users raked this pile down about once a month. The composted contents have not been removed yet, but the owners plan to bury the finished material in an ornamental garden. The owners did not use any insecticides or pest strips.

### HIGHLIGHTS

A problem with moths entering the home was reported, but the outbreak of gnats and *Drosophila* detected by the fly tapes in December and January apparently caused no problem to the occupants.

No liquid buildup or odor problems were reported by the users.

## TABLE 1 UNIT F: MICROBIOLOGICAL DATA

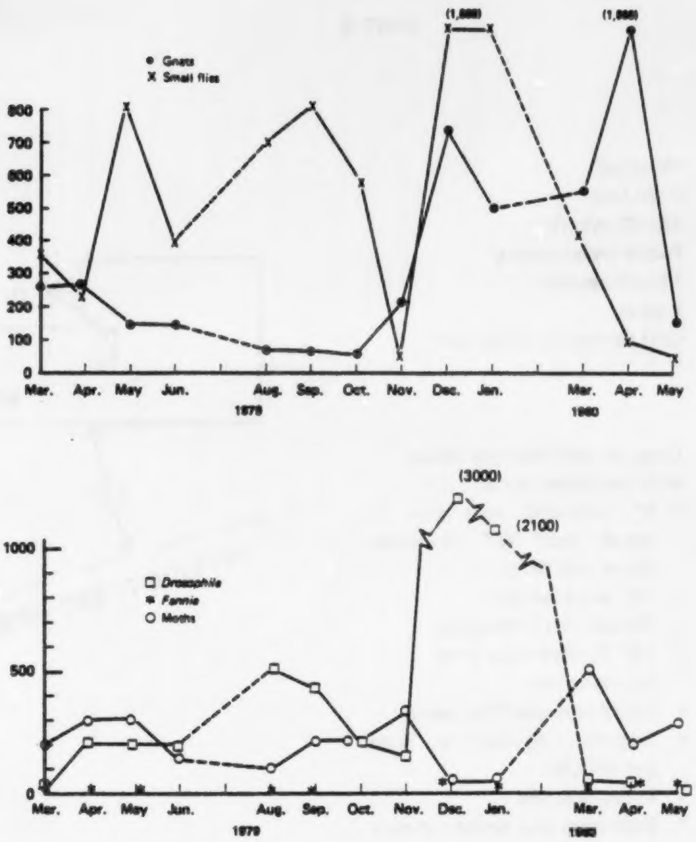
| SAMPLE |  | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type |  |  |  |  |  |
| August 1979 | C | $8.0 \times 10^2$ | $<2.0 \times 10^2$ |  |  |  |
| August 1979 | L | $1.7 \times 10^4$ | $1.1 \times 10^2$ |  |  |  |
| September 1979 | L | $3.3 \times 10^4$ | $1.3 \times 10^2$ |  |  |  |
| October 1979 | C | $7.9 \times 10^4$ | $<2.0 \times 10^2$ |  |  |  |
| October 1979 | L | $2.3 \times 10^3$ | $2.0 \times 10$ |  |  |  |
| November 1979 | C | $5.0 \times 10^2$ | $<2.0 \times 10^2$ |  |  |  |
| November 1979 | L | $3.3 \times 10^3$ | $<2.0 \times 10$ |  |  |  |
| December 1979 | C | $7.0 \times 10^2$ | $<2.0 \times 10^2$ |  |  |  |
| December 1979 | L | $4.9 \times 10^3$ | $<2.0 \times 10$ |  |  |  |
| January 1980 | C | $1.7 \times 10^3$ | $<2.0 \times 10^2$ |  |  |  |
| January 1980 | L | $4.9 \times 10^3$ | $<2.0 \times 10$ |  |  |  |
| March 1980 | C | $8.0 \times 10^2$ | $<2.0 \times 10^2$ |  |  |  |
| March 1980 | L | $3.3 \times 10^4$ | $<2.0 \times 10$ |  |  |  |
| April 1980 | C | $1.3 \times 10^8$ | $4.3 \times 10^5$ | Proteus mirabilis<br>Citrobacter freundii<br>Enterobacter cloacae<br>Proteus morganii<br>Providencia rettgeri<br>Serratia liquefaciens<br>Proteus vulgaris | Finished Compost—Appearance: Finished compost. No parasites found. No known human parasites found. |  |
| April 1980 | L | $4.9 \times 10^5$ | $3.3 \times 10^4$ |  |  |  |
| May 1980 | C | $7.9 \times 10^4$ | $<2.0 \times 10^2$ |  |  |  |
| May 1980 | L | $4.9 \times 10^5$ | $7.1 \times 10^3$ |  |  |  |
| June 1980 | C | $1.1 \times 10^3$ | $<2.0 \times 10^2$ |  |  |  |
| June 1980 | L | $3.3 \times 10^3$ | $<2.0 \times 10$ |  |  |  |
| Finished (C)<br>Geometric Mean<br>Range<br>N = |  | <br>$8.9 \times 10^3$<br>$10^2 - 10^8$<br>9 | <br><br>$<10 - 10^5$<br>9 |  |  |  |

## TABLE 2 UNIT F: SOLID DATA

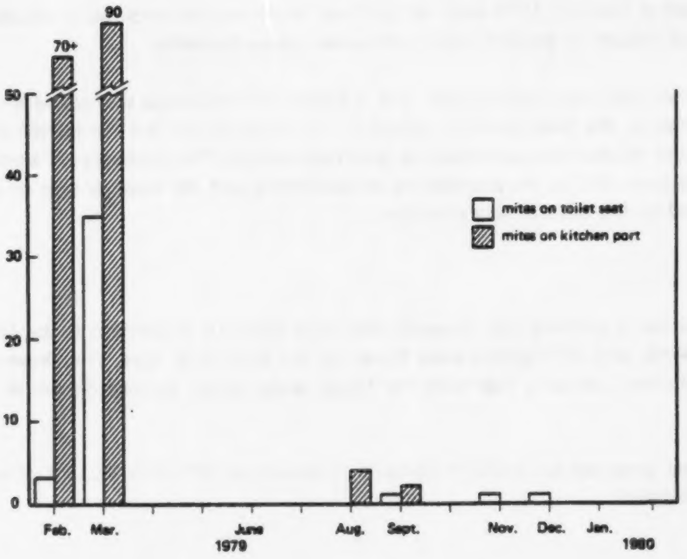
| SAMPLE | | | | | | |
|---|---|---|---|---|---|---|
| Date | Type | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
| August 1979 | C | 4.3 | 45 | 55 | 39 | 61 |
| October 1979 | C | 5.4 | 16 | 85 | 96 | 04 |
| November 1979 | C | 4.6 | 12 | 88 | 87 | 13 |
| December 1979 | C | 5.7 | 32 | 68 | 62 | 38 |
| January 1980 | C | 4.4 | 47 | 53 | 78 | 22 |
| March 1980 | C | 4.8 | 40 | 60 | 34 | 66 |
| April 1980 | C | 3.6 | 35 | 65 | 96 | 04 |
| May 1980 | C | 4.3 | 75 | 25 | 65 | 35 |
| June 1980 | C | 5.1 | 75 | 25 | 70 | 30 |
| Finished (C) | | | | | | |
| Geometric Mean | | 4.6 | 36 | 54 | 66 | |
| Range | | 3.6 – 5.7 | 12 – 75 | 25 – 88 | 34 – 96 | |
| N = | | 9 | 9 | 9 | 9 | |

## TABLE 3 UNIT F: LIQUID DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
| August 1979 | L | 7.0 | 113 | 2,850 | 41,000 | 84 | 1,750 | – | 13,512 | 43,000 |
| September 1979 | L | 6.5 | 36 | 2,610 | 46,530 | 85 | 1,880 | – | 14,410 | 45,200 |
| October 1979 | L | 6.5 | 27 | 2,640 | 46,932 | 155 | 1,408 | – | 14,200 | 45,400 |
| November 1979 | L | 6.3 | 54 | 2,390 | 45,730 | 83 | 1,738 | – | 12,560 | 47,000 |
| December 1979 | L | 6.4 | 28 | 2,322 | 48,180 | 84 | 1,960 | – | 16,834 | 38,800 |
| February 1980 | L | 5.9 | 18 | 2,212 | 38,340 | 380 | – | 1 | 16,200 | 56,000 |
| March 1980 | L | 6.1 | 16 | 1,770 | 40,860 | 390 | 1,140 | < 1 | 1,350 | 33,500 |
| April 1980 | L | 5.5 | 45 | 2,300 | 44,580 | 230 | 1,110 | < 1 | 960 | 33,000 |



GRAPH 1 UNIT F: OCCURRENCE OF FLYING INSECTS

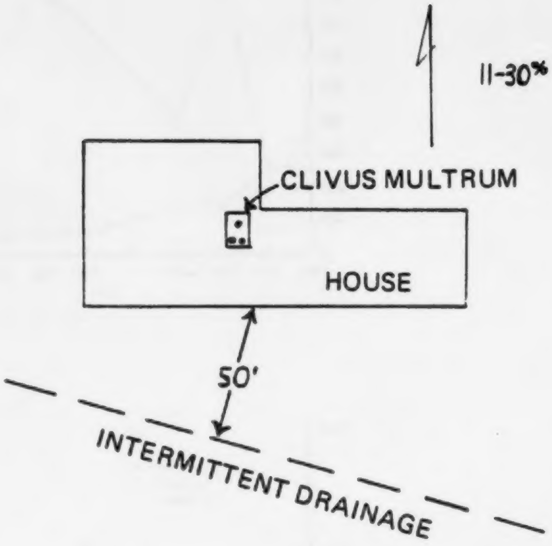


GRAPH 2 UNIT F: OCCURRENCE OF MITES

# UNIT G

## SITE DESCRIPTION

Climate: Mountain
Depth to Groundwater: > 20 feet
Soil Percolation: 45–60 min./in.
Drinking Water Source: Public water supply
Slope: 11–30 percent
Lot Size: 5 acres
Other: Unit located in basement



## UNIT DESIGN

Type: Large, sloped-fiberglas toilet with two toilet ports

Ventilation:
- 6" insulated vent pipe 3' above roof (2" insulation above roof line)
- 10" wind turbine
- Electric fan inside pipe
- 1½" flexible duct wrap

Other:
- No insulation
- Dryer vent used for heater
- External fly-catching tube (jar w/light)
- Toilet seat seal
- Bathroom and kitchen chutes

## SERVICE HISTORY

The unit was installed in October 1979 and has had five full-time users who had a mixed diet. A 50/50 soil/peat moss mixture was used to start up the pile, along with grass and earthworms.

Kitchen wastes (nonanimal) were added daily and a bucket of peat moss was added in the liquid chamber monthly. Sawdust was added to the main chamber monthly. The electric vent fan was turned off at night. The pile was raked down once and the finished contents have not been removed yet. The users sprayed weekly with Pyrethrum, and installed an insecticide pest strip in the composting compartment and an insect jar trap on the side of the unit. These efforts were described by the users as very effective.

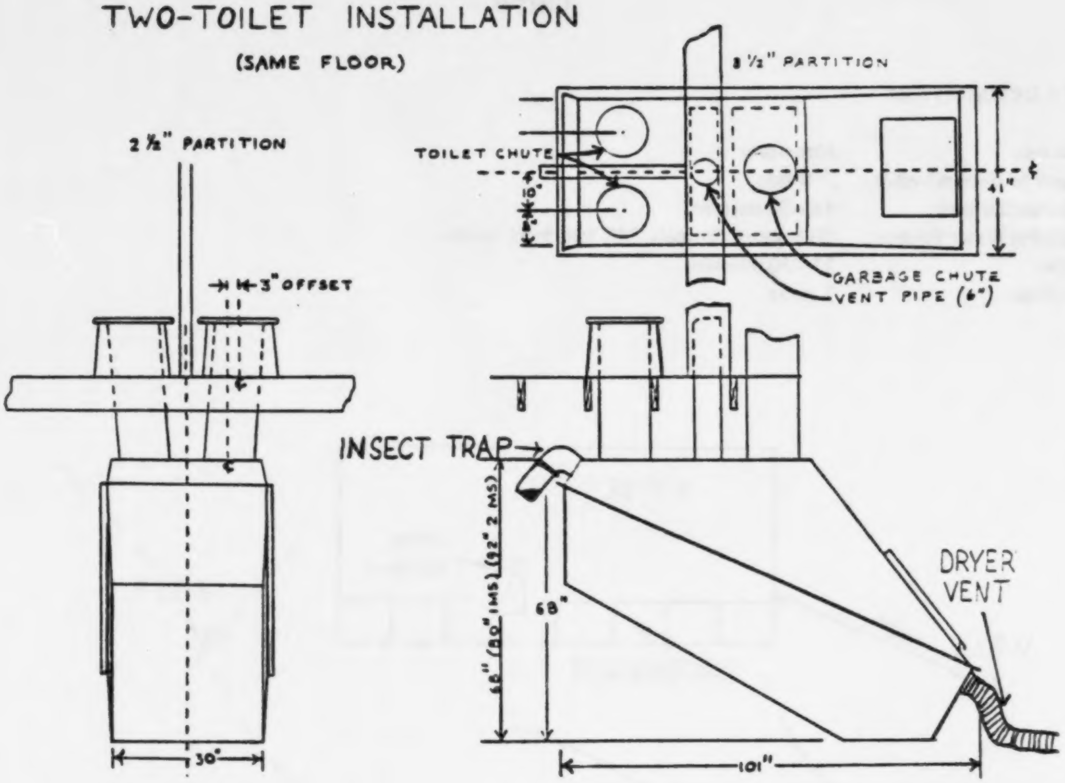
## HIGHLIGHTS

Nonetheless, this unit had a problem with domestic flies since start-up. In addition to the *Drosophila* shown on the fly tape graph, 25 *Fannia* and 25 *Muscina* were found on the November tape. The *Drosophila* seemed under control by June 1980 and other domestic flies were not found again except for one *Fannia* in February and four *Ophyra* in March.

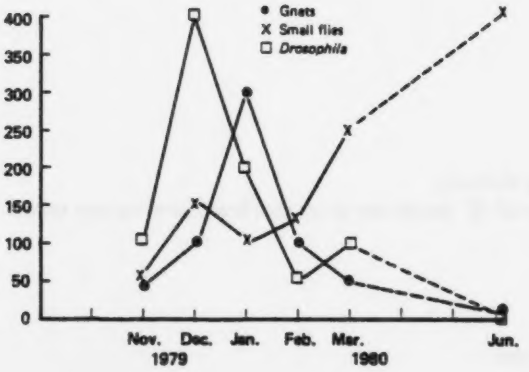
One liquid sample was analyzed for coliform content, it contained $10^4$ MPN/100 ml of total and $10^2$ MPN/100 ml of fecal coliform bacteria.

# TWO-TOILET INSTALLATION

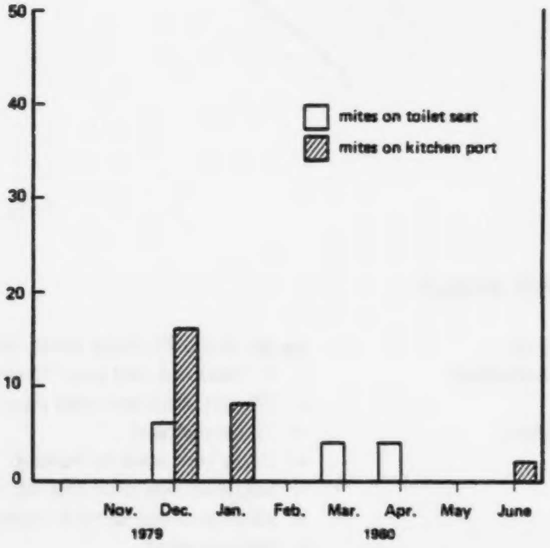
(SAME FLOOR)



2 ½" PARTITION
3" OFFSET
℄
30"
3 ½" PARTITION
TOILET CHUTE
10"
8"
41"
℄
GARBAGE CHUTE
VENT PIPE (6")
INSECT TRAP
68" (80" IMS) (92" 2 MS)
68"
101"
DRYER VENT



GRAPH 1 OCCURRENCE OF FLYING INSECTS

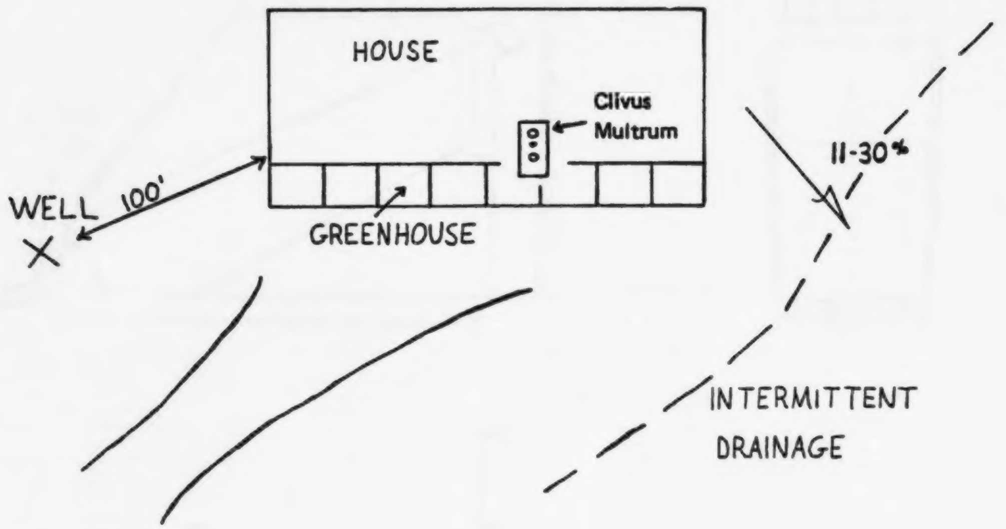


GRAPH 2 OCCURRENCE OF MITES

## UNIT H

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Mountain |
| Depth to Groundwater: | > 8 feet |
| Soil Percolation: | 45–60 min./in. |
| Drinking Water Source: | Well approximately 100 feet from house |
| Slope: | 11–30 percent |
| Lot Size: | 7 acres |

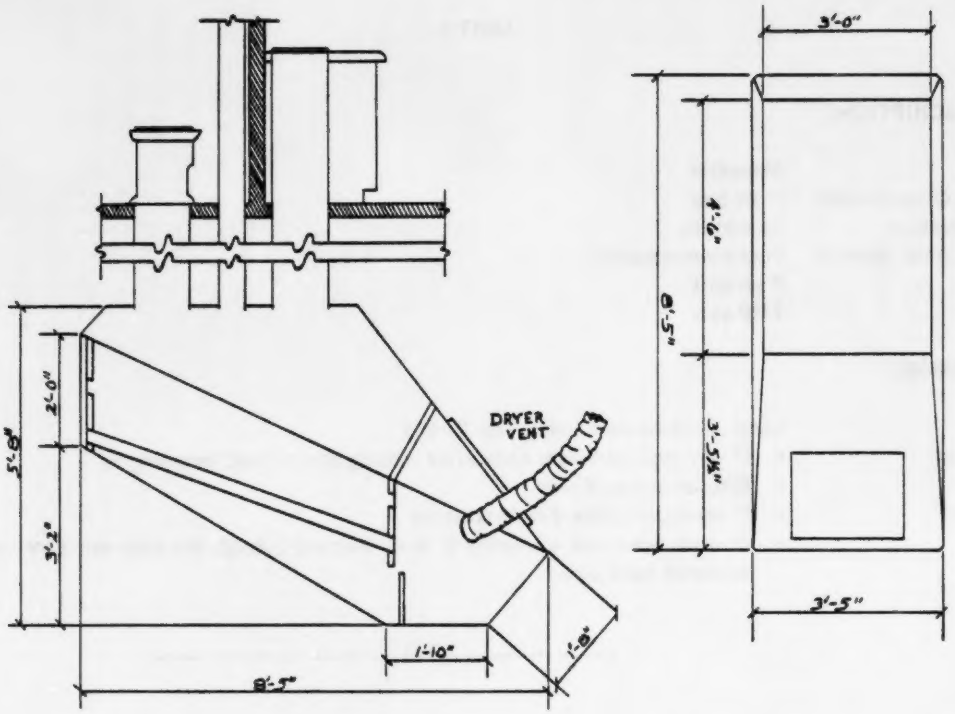

HOUSE
Clivus Multrum
11-30%
WELL
100'
GREENHOUSE
INTERMITTENT DRAINAGE

### UNIT DESIGN

Type: Large, sloped-fiberglas toilet, Clivus Multrum

Ventilation:
- 6" insulated vent pipe through roof (2" insulation above roof line), wind turbine on top
- Electric fan inside vent pipe

Other:
- Toilet seat seal
- Dryer vent used for heating
- Screened vent pipe and vault
- Bathroom and laundry room chutes
- No insulation



LARGE SLOPED FIBERGLAS TOILET

## SERVICE HISTORY

The unit was installed in November 1979 and served two full-time users with four additional users on weekends.

Sawdust, grass clippings, peat moss, and soil which contained worms were used to start up the pile. Kitchen wastes were added daily and sawdust or grass clippings were added monthly.

The fan was used 12 hours/day for the first month but continuously since then. The owner manually turned the pile with a pole through the observation port.

## HIGHLIGHTS

Liquid began to build up after the first months, totaling 12 inches of liquid by February 1980. In March, pine and hardwood sawdust was added to the storage chamber. The sawdust was removed in April and the storage chamber was repacked with sawdust. The liquid buildup condition continued. The users reported no odor or insect problems.

The accumulated liquid was sampled and analyzed during February and May 1980. The total coliform content ranged from $10^6$ to $10^4$ MPN/100 ml and the fecal coliform was less than 50 MPN/100 ml. The analytical results for the February sample are similar to values reported for Unit E.

Five fly tapes were seen from this unit beginning at start-up in November, 1979 through June 1980. Only a few gnats were found on the tapes, indicating successful start-up and maintenance. The mite swabs also showed very few mites on the toilet seat (one in March) and the kitchen port (five each in January and March and one in June).

## UNIT I

### SITE DESCRIPTION

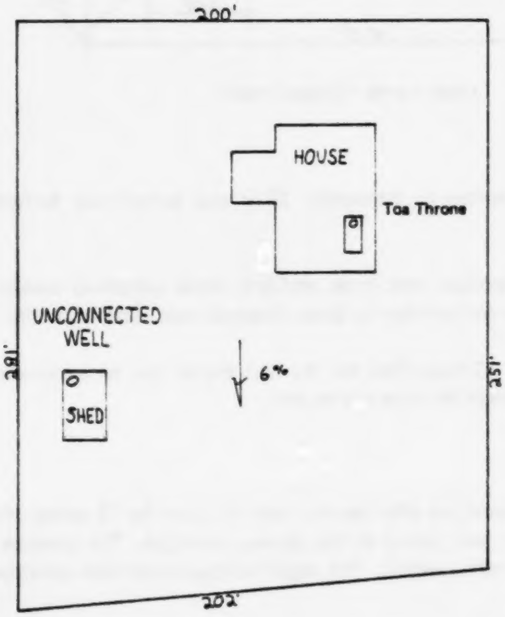
Climate: Mountain
Depth to Groundwater: > 10 feet
Soil Percolation: 21 min./in.
Drinking Water Source: Public water supply
Slope: 6 percent
Lot Size: 7/10 acre

### UNIT DESIGN

Type: Large, sloped-plastic toilet, Toa Throne

Ventilation:
- 4" vent pipe with light bank at air venting inlet to heat incoming air
- 20W fan at top of vent

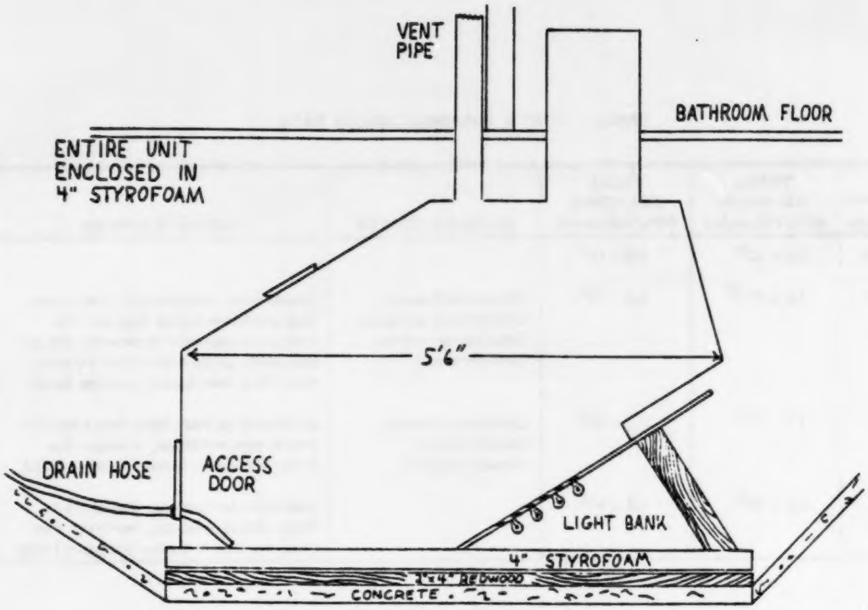
Insulation:
- 4" styrofoam around main chamber
- 1" drain hose, approximately 3' long, inserted through the clean-out panel—attached to a small hand pump



### SERVICE HISTORY

The unit was installed in fall 1976 and has had two full-time users with one or two guests five days per month. The users' diets included some meat.

The unit was started up with grass clippings, peat moss and yard compost; a cup of sawdust was added to the chamber after each use. Kitchen refuse and wood shavings were added weekly and wood ashes (one cup to one pint) were added every six—eight weeks. The composted contents were disposed of every six months with a specially marked shovel, bucket, and gloves. The material was buried in the yard.



## HIGHLIGHTS

Midway through the study (from September 1979—January 1980), the owner added water to "soften" the pile, resulting in leachate buildup from October 1979 to January 1980. In February 1980 the distributor for the unit attempted to remove the material from the unit by chipping the solidified mass. This did not work and the pile was soaked in water to soften for removal in April. The unit was judged a failure by the manufacturer's representative in April 1980 since the air staircase had collapsed under the weight of the pile. The owners discontinued use of the unit in May 1980 when the representative installed another dry toilet (carosel) in a room addition to the home. The nonfunctioning Toa Throne remains in place since neither the owners nor the representative can figure out how to remove it.

The major complaint of the owners was that the waste material did not slide down the air staircase to the container bottom. The attempts at softening led to greater liquid buildup problem which was mitigated with drain hose to the grey water system. The owners described the bolts on the access panel, and the time required to remove them as annoying.

Insects were not controlled with an insecticide strip in the composting compartment. Fly tapes were difficult to hang in this unit and only four were able to be counted. The data are presented in tabular form below.

| | APRIL | AUGUST | SEPTEMBER | JANUARY |
|---|---|---|---|---|
| Gnats | 300 | 400 | 0 | 0 |
| Small flies | 200 | 50 | 100 | 250 |
| *Fannia* | 10 | 20 | 0 | 0 |
| *Muscina* | 5 | 10 | 0 | 0 |
| Moths | 0 | 200 | 200 | 50 |

Mites were taken from two of eight seat swabs (four in April and one in May 1979).

### TABLE 1 UNIT I: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | M | $3.5 \times 10^9$ | $7.9 \times 10^7$ | | | |
| September 1979 | F | $1.6 \times 10^{10}$ | $5.4 \times 10^9$ | Citrobacter freundii<br>Enterobacter aerogenes<br>Enterobacter hafniae<br>Escherichia coli | Appearance: Appears to be fresh feces. Eggs and larvae found. Eggs are thin-shelled and resemble hookworm, but are too small. Larvae—not human parasitic type. No known human parasites found. | |
| October 1979 | F | $1.7 \times 10^8$ | $1.7 \times 10^8$ | Citrobacter freundii<br>Escherichia coli<br>Proteus morganii | Appears to be fresh feces. Few small thin-shelled eggs and larvae, probably free-living. No known human parasites found. | |
| January 1980 | L | $4.9 \times 10^6$ | $1.3 \times 10^6$ | | Leachate—Appearance: Brown liquid. Many ciliates, probably free-living. Few cysts. No known human pathogens found. | |

### TABLE 2 UNIT I: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | M | 8.2 | 36 | 64 | 54 | 46 |
| September 1979 | F | 7.6 | 71 | 29 | 71 | 29 |
| October 1979 | F | 7.1 | 71 | 29 | 62 | 38 |

### TABLE 3 UNIT I: LIQUID DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| October 1979 | L | 7.1 | LE | $2.9 \times 10^3$ | $8.2 \times 10^4$ | 770 | 100 | – | $2.9 \times 10^4$ | $1.1 \times 10^5$ |
| January 1980 | L | 8.0 | LE | $6.2 \times 10^3$ | $4.4 \times 10^4$ | $1.5 \times 10^3$ | 460 | – | $1.1 \times 10^4$ | $4.3 \times 10^4$ |

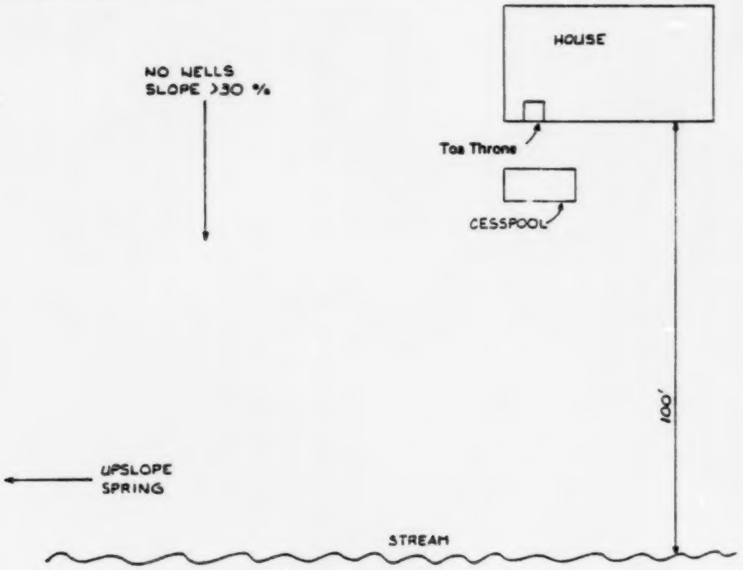
# UNIT J

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | > 3 feet |
| Soil Percolation: | < 45 min./in. |
| Drinking Water Source: | Upslope spring |
| Slope: | > 30 percent |
| Lot Size: | 200 acres |
| Other: | • Chamber located beneath house<br>• Chicken wire screen around basement |

## UNIT DESIGN

| | |
|---|---|
| Type: | Large, sloped-plastic toilet, Toa Throne |
| Ventilation: | 4" plastic vent pipe, 15' high, with electric fan |
| Insulation: | 1" foam rubber taped to vault |
| Other: | Toilet seat seal |



## SERVICE HISTORY

The unit has been in operation since 1977 and in the study from October 1979.

Before December 1979 two persons used the unit with no urine addition. Soil and peat moss started the unit and the users added kitchen waste, especially wet plant waste regularly. In one instance, waste from a wine-making endeavor was added. The contents were removed every other year and further decomposed in a garden compost pile using an unmarked shovel. The users attempted to control fruit flies with weekly pyrethrum sprayings and sticky tapes.

## HIGHLIGHTS

The pile dried out in December 1979 and the owner used a rake to break up the crust which resulted in an immediate improvement. From January 1980 two people began using the unit. The unit received urine at that time as well as the regular addition of wet kitchen wastes. For a two-week period in February five adults used the unit which aggravated the liquid buildup problem and resulted in a very wet pile mass. The unit was bulging at the sides and the air staircase was threatening to collapse as it did for Units I and K as the study observations ended. The unit was to be abandoned soon in any case since a flush toilet was being installed onto a new septic tank leach field system.

Counts of flying insects taken from four tapes are presented in tabular form below. The high counts of *Drosophila* in May and June 1980 were caused by grape pressings put into the unit. Two swabs out of six swabs taken detected mites on the toilet seat (two in December and four in January).

| | OCTOBER | JANUARY | MAY | JUNE |
|---|---|---|---|---|
| Gnats | 300 | 2 | 10 | 70 |
| Small flies | 200 | 1 | 50 | 5 |
| *Drosophila* | 0 | 0 | 50 | 200 |
| *Fannia* | 0 | 0 | 0 | 20 |

## TABLE 1 UNIT J: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| October 1979 | C | $2.2 \times 10^3$ | $<2.0 \times 10^2$ | | | |
| December 1979 | C | $1.7 \times 10^7$ | $2.3 \times 10^2$ | | | |
| January 1980 | C | $7.0 \times 10^5$ | $<2.0 \times 10^2$ | | | |
| March 1980 | C | $3.3 \times 10^5$ | $<2.0 \times 10^2$ | | | |
| March 1980 | L | $1.3 \times 10^6$ | $2.0 \times 10$ | | | |
| April 1980 | C | $1.3 \times 10^3$ | $<2.0 \times 10^2$ | | | |
| April 1980 | L | $7.9 \times 10^4$ | $<2.0 \times 10$ | | | |
| May 1980 | L | $4.6 \times 10^6$ | $8.0 \times 10$ | | | |
| June 1980 | C | $3.3 \times 10^6$ | $<2.0 \times 10^2$ | | | |
| June 1980 | L | $2.3 \times 10^5$ | $2.3 \times 10^2$ | | | |
| **Finished (C)** | | | | | | |
| Geometric Mean | | $1.8 \times 10^5$ | $<2.0 \times 10^2$ | | | |
| Range | | $10^3 - 10^7$ | $<10^2 - 10^2$ | | | |
| N = | | 6 | 6 | | | |
| **Leachate (L)** | | | | | | |
| Geometric Mean | | $1.6 \times 10^6$ | | | | |
| Range | | $10^5 - 10^6$ | | | | |
| N = | | 4 | | | | |

## TABLE 2 UNIT J: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| October 1979 | C | – | 9 | 91 | 51 | 49 |
| December 1979 | C | 6.0 | 57 | 43 | 45 | 55 |
| January 1979 | C | 5.6 | 64 | 36 | 52 | 48 |
| March 1980 | C | 6.8 | 78 | 22 | 44 | 56 |
| April 1980 | C | 6.3 | 2 | 98 | 10 | 90 |
| June 1980 | C | 7.3 | 75 | 25 | 66 | 34 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 6.4 | 47 | 53 | 39 | 53 |
| Range | | 5.6 – 7.3 | 2 – 78 | 22 – 98 | 10 – 66 | 34 – 90 |
| N = | 5 | 6 | 6 | 6 | 6 | 6 |

## TABLE 3 UNIT J: LIQUID DATA

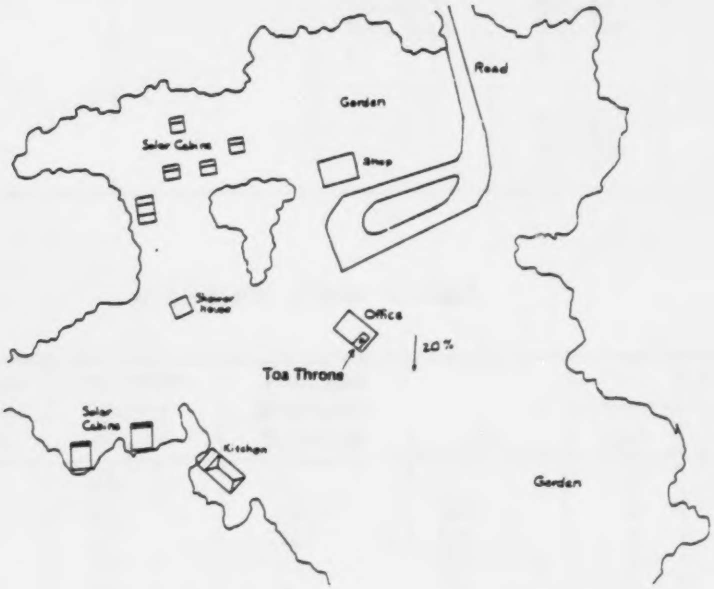
| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC μmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| March 1980 | L | 7.2 | LE | $5.5 \times 10^3$ | $3.9 \times 10^4$ | $1.7 \times 10^3$ | 680 | 27.4 | $1.1 \times 10^4$ | $3.6 \times 10^4$ |
| April 1980 | L | 7.7 | LE | $6.8 \times 10^3$ | $4.0 \times 10^4$ | 900 | 800 | 67.3 | $8.5 \times 10^3$ | $2.3 \times 10^4$ |

LE = Laboratory Error

## UNIT K

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 120 feet |
| Soil Percolation: | 120 min./in. (soil type: clay loam over sandstone) |
| Depth to Bedrock: | > 4 feet |
| Slope: | 20 percent |
| Lot Size: | 1 acre to nearest residence |
| Other: | • Chamber installed beneath house on native soil<br>• There are many waterless toilets located on the site |



### UNIT DESIGN

| | |
|---|---|
| Type: | Large, sloped-plastic toilet, Toa Throne |
| Ventilation: | • 4" PVC pipe, topped with a 6" wind turbine cap<br>• Pipe portion from roofline to turbine packed with styrofoam beads for insulation |
| Insulation: | Roll insulation (R-11) between studs of frame structure which houses unit beneath floor. |
| Other: | • 5-gallon drum for urine separation (installed March 1980)<br>• Pest strips<br>• Specially marked large shovel and pitchfork to handle contents<br>• Siphon system (installed January 1980)<br>• Counter on lid<br>• Screens on chamber housing walls and vent pipe<br>• Rubber seal on toilet seat<br>• Enclosed in plywood stud "basement"<br>• Two access doors |

## SERVICE HISTORY

This unit was installed in an office facility in June 1978, and was intended for four full-time users. The unit averaged six uses per day and was used mainly by office staff for urination. The staff started the unit by placing straw on the sloped bottom and sawdust on the finished chamber floor. On top of this bedding they placed garden compost (grass, soil, fresh garbage, leaf mold, earth worms) and approximately 10 gallons of citrus fruit scraps. After each use a handful of chopped straw or fresh grass was added to the unit. The seat was kept closed when not in use.

Weekly maintenance was prompted by liquid buildup and odor problems; however, the pile was never mixed or turned. The contents were removed in December 1979 after approximately two years of storage and will be stored in a bin for approximately one year before burial around ornamental trees.

## HIGHLIGHTS

The unit experienced a liquid buildup problem throughout the study. In March 1979, approximately 16 gallons of liquid were removed after an overflow occurred through the bottom inspection plate. By June 1979, liquid had accumulated in the finished chamber, and in January 1980 liquid overflowed out the access door several times. At this time the staff installed a siphon system to remove the liquid (approximately 7–8 gallons per month) for subsurface disposal. In March 1980 the staff posted a sign requesting that people not urinate in the unit (except when defecating) and, instead, suggested use of a separate 5-gallon drum. The urine was disposed of by soaking it into a newly dug trench.

Problems associated with the weight of the wet wastes and the liquid buildup were:

1. Bulging of unit's sides
2. Flattening of air baffles
3. Inundation of finished wastes and generation of unpleasant odors caused by anaerobic conditions ($H_2S$ or $NH_3$ smell noted on eight sanitarian visits)
4. Corrosion of metal bolts and hatch door

A severe insect problem (fruit flies and mites) was reported during the first four months of operation and the users stopped adding food scraps in February 1979. Pest strips, ammonia and wood ashes were moderately effective as control devices. Signs of rats and mice were observed on almost every sanitarian visit and, during the course of the study, a skunk set up residence in the structure and damaged the insulation.

Other problems and corrections:

- Redwood and fir sawdust were thought to decompose slowly and its use was stopped
- Ventilation problems caused by high trees, which inhibited wind turbine rotation, was corrected by tree thinning
- Rubber toilet seal fell apart

Although the waste contents were infrequently manipulated and recognizeable composting did not occur, the staff members were quite adverse to the level of maintenance actually practiced. The unit was judged unacceptable and the staff intend to abandon use of the unit in favor of a low volume flush toilet.

## TABLE 1 UNIT K: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | $2.4 \times 10^9$ | $2.4 \times 10^9$ | Citrobacter freundii | Appearance: Appears to be fresh feces. Eggs and live larvae found. Eggs resemble hookworm type. Larvae resemble free-living. | None Isolated |
| August 1979 | L | $4.9 \times 10^6$ | $4.9 \times 10^6$ | | | |
| September 1979 | F | $5.4 \times 10^9$ | $5.4 \times 10^9$ | Proteus vulgaris<br>Edwardsiella tarda<br>Enterobacter cloacae | Appearance: Appears to be feces with grass. Many larvae, one viable probably free-living, few small thin-shelled eggs. No known human parasites found. | |
| October 1979 | F | $2.3 \times 10^8$ | $1.3 \times 10^8$ | Citrobacter freundii<br>Proteus vulgaris<br>Proteus morganii<br>Providencia rettgeri | Appears to be feces mixed with straw. Few larvae, thin-shelled eggs and cyst-like objects. Probably free-living organisms. No known human parasites found. | |
| October 1979 | L | $7.9 \times 10^5$ | $7.0 \times 10^4$ | | | |
| November 1979 | L | $1.3 \times 10^7$ | $1.1 \times 10^5$ | Proteus morganii<br>Yersinia enterocolitica<br>Citrobacter freundii<br>Proteus mirabilis | Appearance: Brown liquid; few ciliates, few small thin-shelled eggs, moderate number of larvae, probably free-living. No known human pathogens found. | None Isolated |
| December 1979 | C | $9.2 \times 10^9$ | $9.2 \times 10^9$ | | | |
| December 1979 | L | $3.3 \times 10^5$ | $2.3 \times 10^4$ | Citrobacter diversus-levinea<br>Proteus vulgaris<br>Citrobacter freundii<br>Enterobacter cloacae<br>Proteus morganii | Leachate—Appearance: Brown liquid. Moderate number of dead larvae, probably free-living. Many ciliates. Few thin-shelled eggs. No known human parasites found. | None Isolated |
| January 1980 | C | $2.4 \times 10^{10}$ | $2.4 \times 10^{10}$ | Escherichia coli<br>Citrobacter freundii<br>Enterobacter cloacae<br>Citrobacter diversus-levinea<br>Proteus morganii<br>Proteus vulgaris<br>Pseudomonas putrefaciens | Finished Compost—Appearance: Feces with straw. Few mite eggs, few eggs and larvae, probably free-living. Few cyst-like objects. No known human pathogens found. | None Isolated |

TABLE 1 UNIT K: MICROBIOLOGICAL DATA (Continued)

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| January 1980 | L | $1.7 \times 10^7$ | $1.7 \times 10^7$ | Citrobacter freundii<br>Hafnia alvei<br>Enterobacter cloacae<br>Providencia rettgeri<br>Proteus mirabilis<br>Proteus vulgaris<br>Klebsiella oxytoca<br>Klebsiella pneumoniae | Leachate—Appearance: Brown liquid. Many flagellates, free-living. Few free-living ciliates. Occasional larvae, probably free-living. No known human pathogens found. | None Isolated |
| February 1980 | C | $9.2 \times 10^9$ | $9.2 \times 10^9$ | | | |
| February 1980 | L | $1.3 \times 10^6$ | $7.9 \times 10^5$ | Citrobacter freundii<br>Proteus morganii<br>Providencia rettgeri<br>Proteus rettgeri<br>Proteus mirabilis<br>Proteus vulgaris<br>Escherichia coli<br>Klebsiella rhinoscleromatis | Leachate—Appearance: Brown liquid. Many flagellates and ciliates, probably free-living. No known human parasites found. | |
| March 1980 | C | $1.1 \times 10^9$ | $1.3 \times 10^8$ | | | |
| March 1980 | L | $2.2 \times 10^6$ | $1.3 \times 10^6$ | | | |
| April 1980 | C | $1.7 \times 10^9$ | $7.9 \times 10^8$ | | | |
| April 1980 | L | $1.3 \times 10^6$ | $7.9 \times 10^5$ | | | |
| May 1980 | C | $1.3 \times 10^8$ | $4.9 \times 10^7$ | | | |
| May 1980 | L | $1.1 \times 10^7$ | $2.3 \times 10^6$ | | | |
| June 1980 | C | $1.6 \times 10^{10}$ | $1.6 \times 10^{10}$ | | | |
| June 1980 | L | $2.3 \times 10^6$ | $1.3 \times 10^6$ | | | |
| **Liquid (L)** | | | | | | |
| Geometric Mean | | $2.7 \times 10^6$ | $7.2 \times 10^5$ | | | |
| Range | | $10^5 - 10^7$ | $10^4 - 10^7$ | | | |
| N = | | 10 | 10 | | | |
| **Finished (C)** | | | | | | |
| Geometric Mean | | $3.9 \times 10^9$ | $2.1 \times 10^9$ | | | |
| Range | | $10^8 - 10^{10}$ | $10^8 - 10^{10}$ | | | |
| N = | | 7 | 7 | | | |

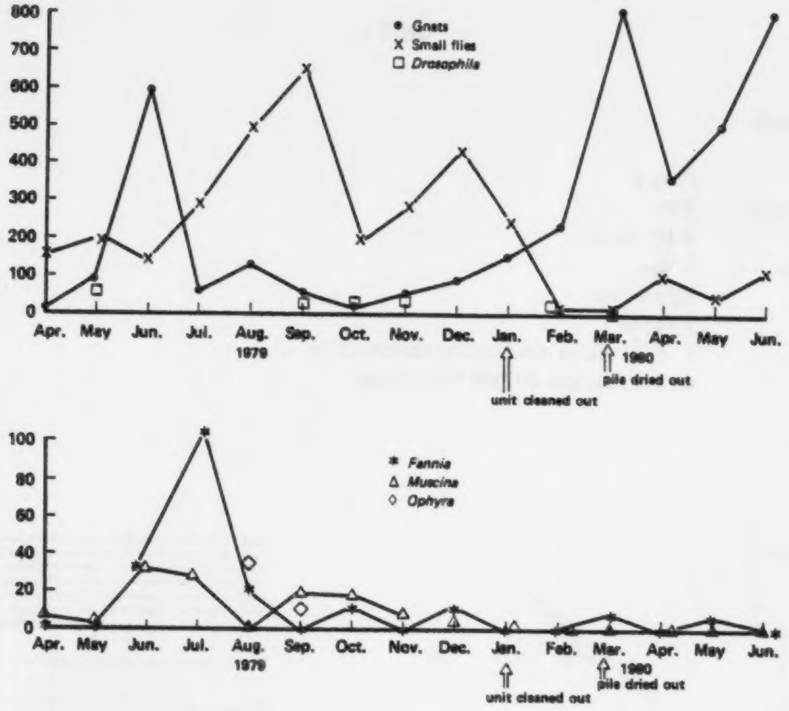
## TABLE 2 UNIT K: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | 7.4 | 72 | 28 | 76 | 24 |
| September 1979 | F | 7.2 | 74 | 27 | 85 | 15 |
| October 1979 | F | 7.3 | 81 | 19 | 82 | 18 |
| December 1979 | C | 7.6 | 81 | 19 | 74 | 26 |
| January 1980 | C | 7.0 | 72 | 28 | 70 | 30 |
| February 1980 | C | 6.8 | 83 | 17 | 63 | 37 |
| March 1980 | C | 7.1 | 80 | 20 | 74 | 26 |
| April 1980 | C | 7.4 | 79 | 22 | 71 | 29 |
| May 1980 | C | 7.6 | 83 | 17 | 62 | 38 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 7.2 | 80 | 29 | 69 | 31 |
| Range | | 6.8 – 7.6 | 72 – 83 | 17 – 28 | 62 – 74 | 26 – 38 |
| N = | | 6 | 6 | 6 | 6 | 6 |

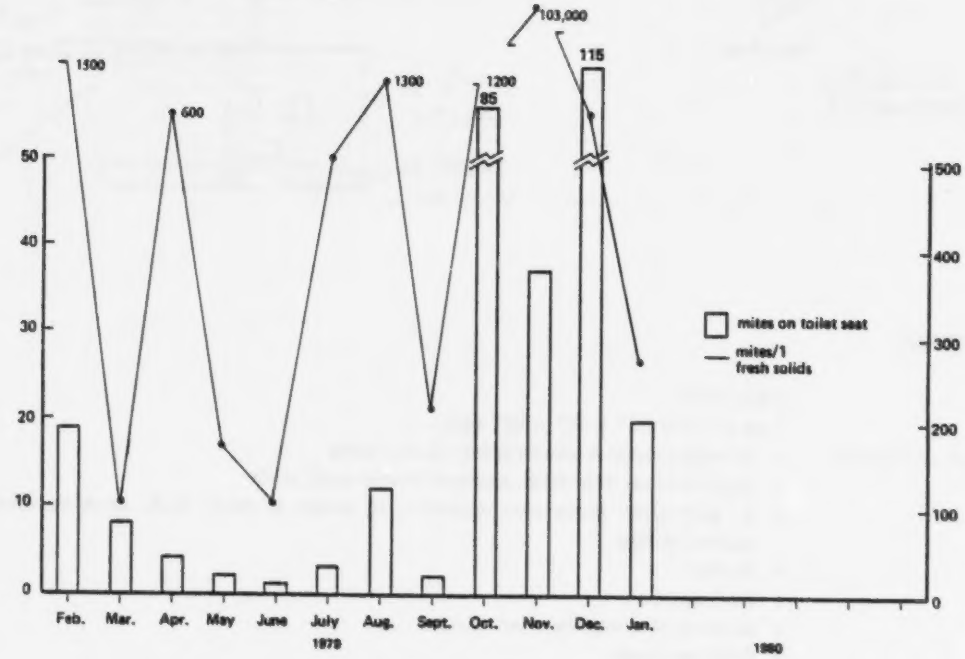
## TABLE 3 UNIT K: LIQUID DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC μmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| August 1979 | L | 7.8 | LE | $6.7 \times 10^3$ | $2.3 \times 10^4$ | 560 | 790 | – | 4.4 | $2.7 \times 10^4$ |
| September 1979 | L | 7.9 | LE | $6.5 \times 10^3$ | $2.5 \times 10^4$ | 210 | 560 | – | 5.3 | $2.1 \times 10^4$ |
| October 1979 | L | 8.0 | LE | $6.7 \times 10^3$ | $2.4 \times 10^4$ | 20 | 510 | – | 3.5 | $2.5 \times 10^4$ |
| November 1979 | L | 8.2 | $2.3 \times 10^3$ | $8.2 \times 10^3$ | $2.3 \times 10^4$ | 190 | 660 | – | 4.4 | $2.4 \times 10^4$ |
| December 1979 | L | 7.3 | LE | $9.1 \times 10^3$ | $2.2 \times 10^4$ | 340 | 750 | – | 113.7 | $1.9 \times 10^4$ |
| January 1980 | L | 7.9 | LE | $9.9 \times 10^3$ | $2.1 \times 10^4$ | 230 | 560 | – | $<0.1$ | $1.8 \times 10^4$ |
| February 1980 | L | 7.3 | $1.8 \times 10^3$ | $1.2 \times 10^4$ | $2.0 \times 10^4$ | 570 | 670 | – | $<0.1$ | $1.9 \times 10^4$ |
| March 1980 | L | 7.6 | $3.1 \times 10^3$ | $1.1 \times 10^4$ | $2.1 \times 10^4$ | $3.8 \times 10^3$ | 890 | – | $<2.2$ | $2.2 \times 10^4$ |
| April 1980 | L | 7.2 | $2.2 \times 10^3$ | $2.9 \times 10^4$ | $2.1 \times 10^4$ | $3.8 \times 10^3$ | 630 | – | 4.4 | $1.8 \times 10^4$ |
| **Liquid (L)** | | | | | | | | | | |
| Geometric Mean | | 7.7 | $2.3 \times 10^3$ | $9.8 \times 10^3$ | $2.2 \times 10^4$ | 404 | 659 | – | 2.5 | $2.1 \times 10^4$ |
| Range | | 7.3 – 8.2 | $10^3$ | $10^3 - 10^4$ | $10^4$ | $10 - 10^3$ | $10^2$ | – | $<0.1 - 114$ | $10^4$ |
| N = | | 9 | 4 | 9 | 9 | 9 | 9 | – | 9 | 9 |

LE = Laboratory Error



GRAPH 1 OCCURRENCE OF FLYING INSECTS

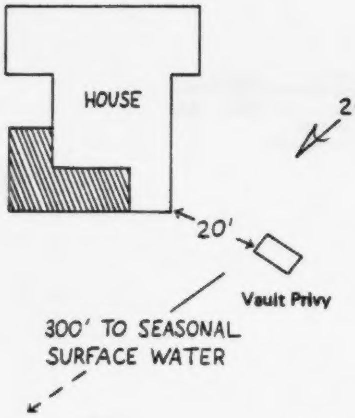


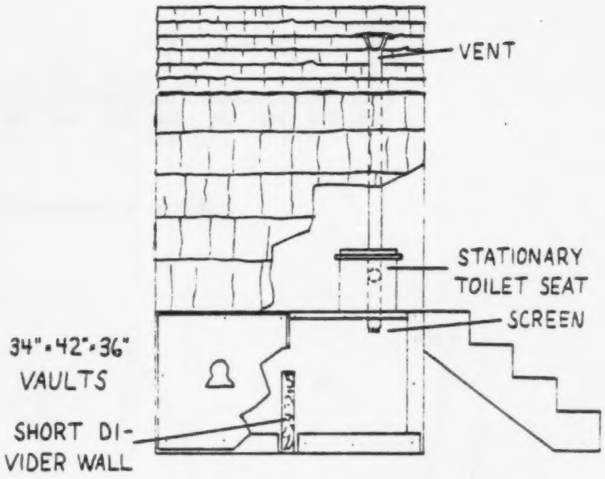
GRAPH 2 OCCURENCE OF MITES

## UNIT L

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater | 300+ |
| Soil Percolation: | > 60 min./in. |
| Depth to Bedrock: | 4 feet |
| Slope: | 20 percent |
| Lot Size: | 20 acres |
| Other: | • Excavation required for construction<br>• Unit located 20 feet from house |


HOUSE
20%
20'
Vault Privy
300' TO SEASONAL SURFACE WATER


VENT
STATIONARY TOILET SEAT
SCREEN
34"×42"×36" VAULTS
SHORT DIVIDER WALL

### UNIT DESIGN

| | |
|---|---|
| Type: | Vault privy |
| Size: | Two vaults @ 34" x 42" x 36" each |
| Construction Material: | • Shingled, wood frame structure above vaults<br>• Concrete slab floor with rock and mortar vault walls |
| Ventilation: | • 3" galvanized metal pipe extending to height of room peak; screened inside vault; capped on top<br>• No fan |
| Other: | • No insulation<br>• Short divider wall between vaults<br>• Stationary seat<br>• Toilet lid seal (with clamps)<br>• No screen in service hatch hole |

## SERVICE HISTORY

Installed in mid-1976, the unit accommodated two adults full time. Their diets included some meat.

Pine and fir sawdust was used to start up the pile. The owner added two cups of fir sawdust after each use and manually turned the "fresh" pile once a month. Earthworms were added to the "aging" chamber. Because the toilet seat was stationary the owner had to first remove the "finished" material from the aging chamber for disposal incorporating it into a garden compost pile, and then move the fresher material into the aging side every six to eight months.

## HIGHLIGHTS

During the rainy months the chamber showed liquid accumulation probably due to groundwater infiltration. Overflow occurred at the front lip of the vault. Sticky tapes were used in an attempt to control flies. Owners reported that odors and liquid buildup were no problem. It should be noted that the owners of this unit were very responsible maintaining the unit, but the very high numbers of domestic flies found in the vaults indicated extensive fly breeding.

In addition to the high numbers of *Fannia, Muscina,* and *Ophyra* found in this unit, an infestation of *Stomoxys calcitrans*, the biting stable fly, was detected by the fly tapes in November and December (20 each on the fresh chamber tapes, and ten and eight respectively on the storage chamber tapes). This emergence of adult stable flies would indicate the larval breeding occurred in September and October.

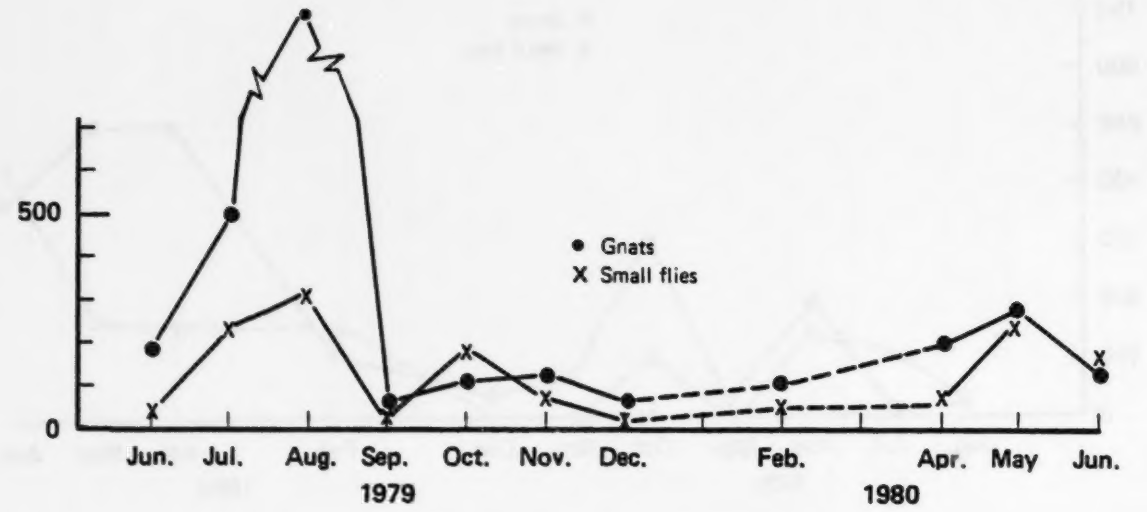
Mites were found on four out of ten swabs of the toilet seat (one each in August and September and four each in October 1979 and April 1980.

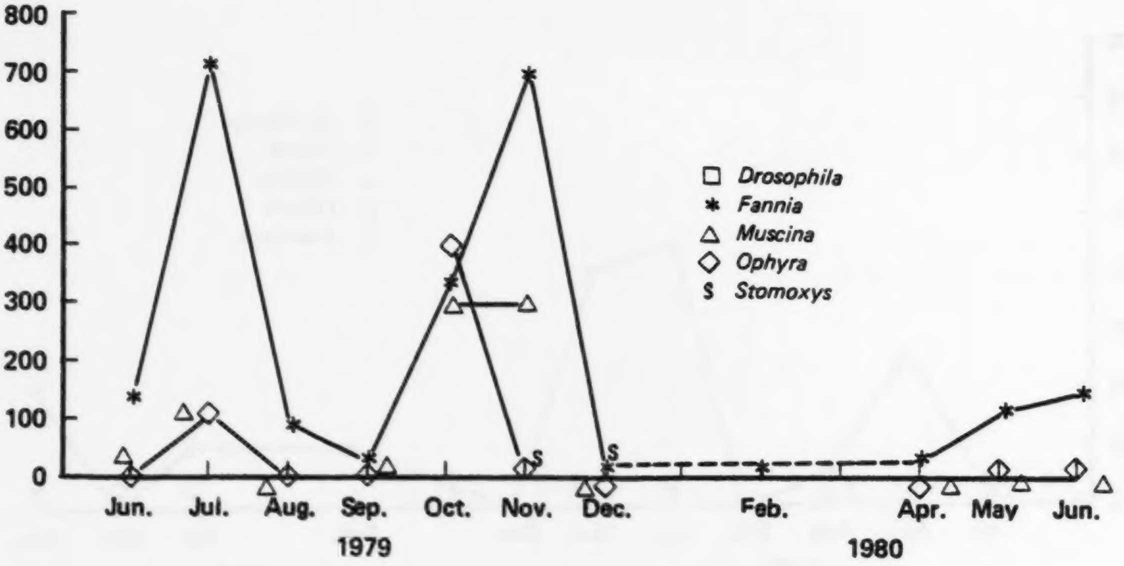
### TABLE 1 UNIT L: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $3.3 \times 10^7$ | $5.0 \times 10^2$ | | | | 0 month storage |
| September 1979 | C | $7.9 \times 10^7$ | $2.3 \times 10^4$ | | | | 1 month storage |
| October 1979 | C | $2.3 \times 10^7$ | $2.3 \times 10^6$ | | | | 2 months storage |
| November 1979 | C | $7.9 \times 10^6$ | $3.1 \times 10^5$ | | | | 3 months storage |
| December 1979 | C | $1.4 \times 10^6$ | $4.9 \times 10^5$ | | | | 4 months storage |
| February 1980 | C | $1.1 \times 10^7$ | $4.6 \times 10^4$ | | | | |
| April 1980 | C | $1.7 \times 10^9$ | $4.9 \times 10^7$ | Citrobacter diversus-levinea<br>Enterobacter cloacae<br>Proteus mirabilis<br>Providencia rettgeri<br>Proteus vulgaris<br>Pseudomonas aeruginosa<br>Klebsiella pneumoniae | Finished Compost—Appearance: Finished compost. Occasional larvae, probably free-living. No known human parasites found. | | |
| May 1980 | C | $\geq 2.4 \times 10^{10}$ | $1.6 \times 10^{10}$ | | | | |
| June 1980 | C | $2.2 \times 10^9$ | $1.3 \times 10^7$ | | | | |
| **Finished (C)** | | | | | | | |
| Geometric Mean | | $5.6 \times 10^7$ | $1.1 \times 10^6$ | | | | |
| Range | | $10^6 - 10^9$ | $10^2 - 10^{10}$ | | | | |
| N = | | 8 | 9 | | | | |

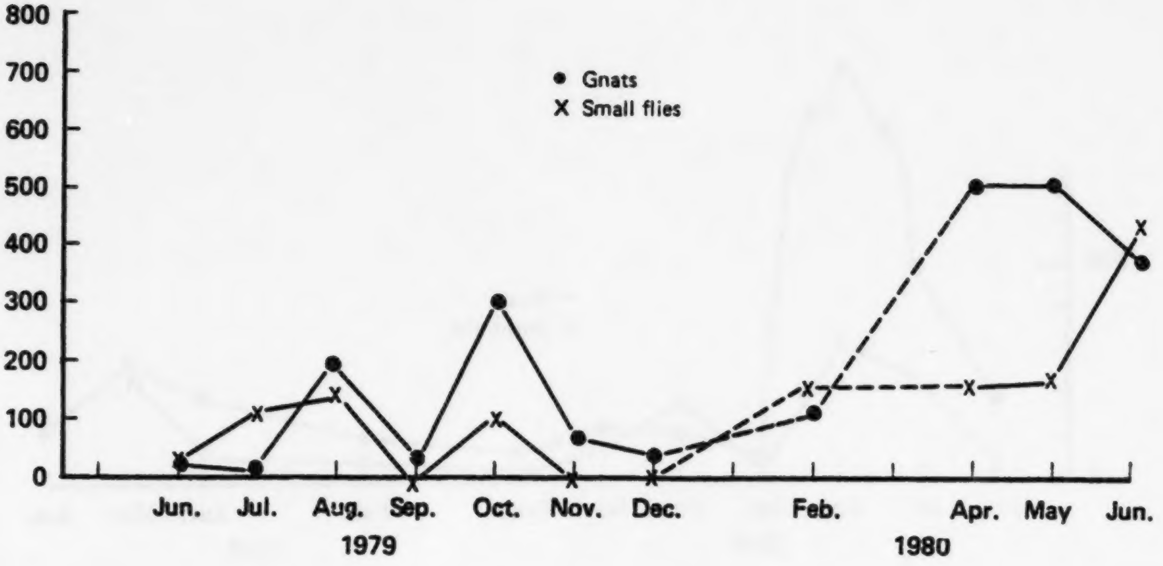
### TABLE 2 UNIT L: SOLID DATA

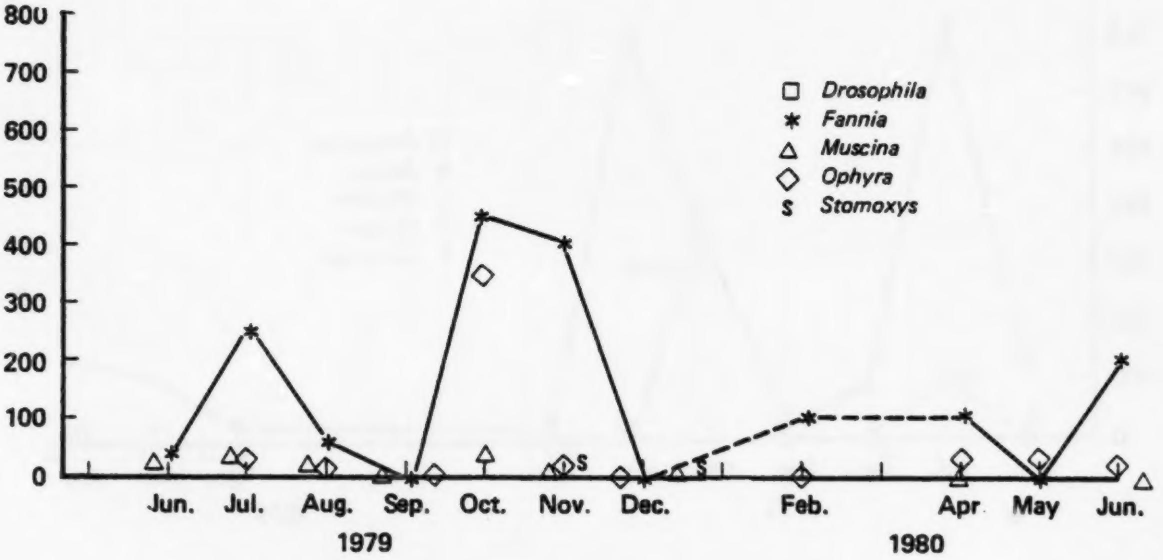
| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 5.4 | 62 | 38 | 87 | 13 |
| September 1979 | C | 5.6 | 73 | 27 | 81 | 19 |
| October 1979 | C | 5.6 | 64 | 36 | 71 | 29 |
| November 1979 | C | 5.2 | 69 | 31 | 75 | 25 |
| December 1979 | C | 5.6 | 67 | 33 | 83 | 17 |
| February 1980 | C | 4.9 | 67 | 33 | 91 | 9 |
| April 1980 | C | 7.4 | 69 | 31 | 92 | 8 |
| May 1980 | C | 6.9 | 68 | 32 | 79 | 21 |
| June 1980 | C | 4.5 | 68 | 32 | 87 | 13 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 5.6 | 67 | 32 | 83 | 16 |
| Range | | 4.5 – 7.4 | 62 – 73 | 27 – 38 | 71 – 92 | 8 – 29 |
| N = | | 9 | 9 | 9 | 9 | 9 |





GRAPH 1 UNIT L: IN-USE CHAMBER



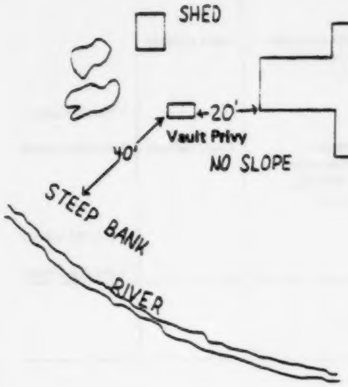


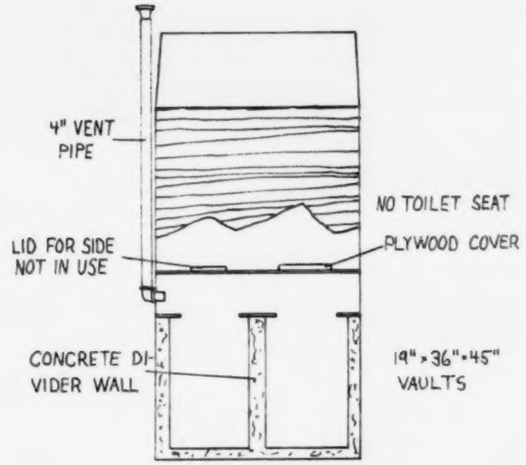
GRAPH 2 UNIT L: AGING CHAMBER

## UNIT M

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | N.A. |
| Soil Percolation: | N.A. |
| Drinking Water Source: | Spring |
| Slope: | 0 percent |
| Lot Size: | 32 acres |


SHED
HOUSE
20'
Vault Privy
40'
NO SLOPE
STEEP BANK
RIVER


4" VENT PIPE
NO TOILET SEAT
LID FOR SIDE NOT IN USE
PLYWOOD COVER
CONCRETE DI-VIDER WALL
19"×36"×45" VAULTS

### UNIT DESIGN

| | |
|---|---|
| Type: | Vault privy |
| Size: | Two vaults @ 19" x 36" x 45" each |
| Construction Material: | Poured-in-place concrete vaults |
| Ventilation: | 4" orangeburg riser vents from each vault to 12" above roof line; no screen |
| Other: | • Vaults completely separate<br>• Screened vent pipes<br>• No screen in service hatch |

### SERVICE HISTORY

Installed in May 1978, the unit accommodated six full-time users whose diets included some meat.

Fir sawdust was used to start up the pile and to maintain it (two cups after each use). The sanitarian reported large amounts of sawdust being used. The aged wastes are disposed of under conifers and fruit trees every six months at which time the toilet seat is moved over the newly emptied vault. The in-use vault's contents were turned with an unmarked shovel or rake.

### HIGHLIGHTS

Odors and insects were controllable problems according to the owners, and liquid buildup was no problem at all. The owners minimally maintained the unit and in some instances the unit apeared neglected.

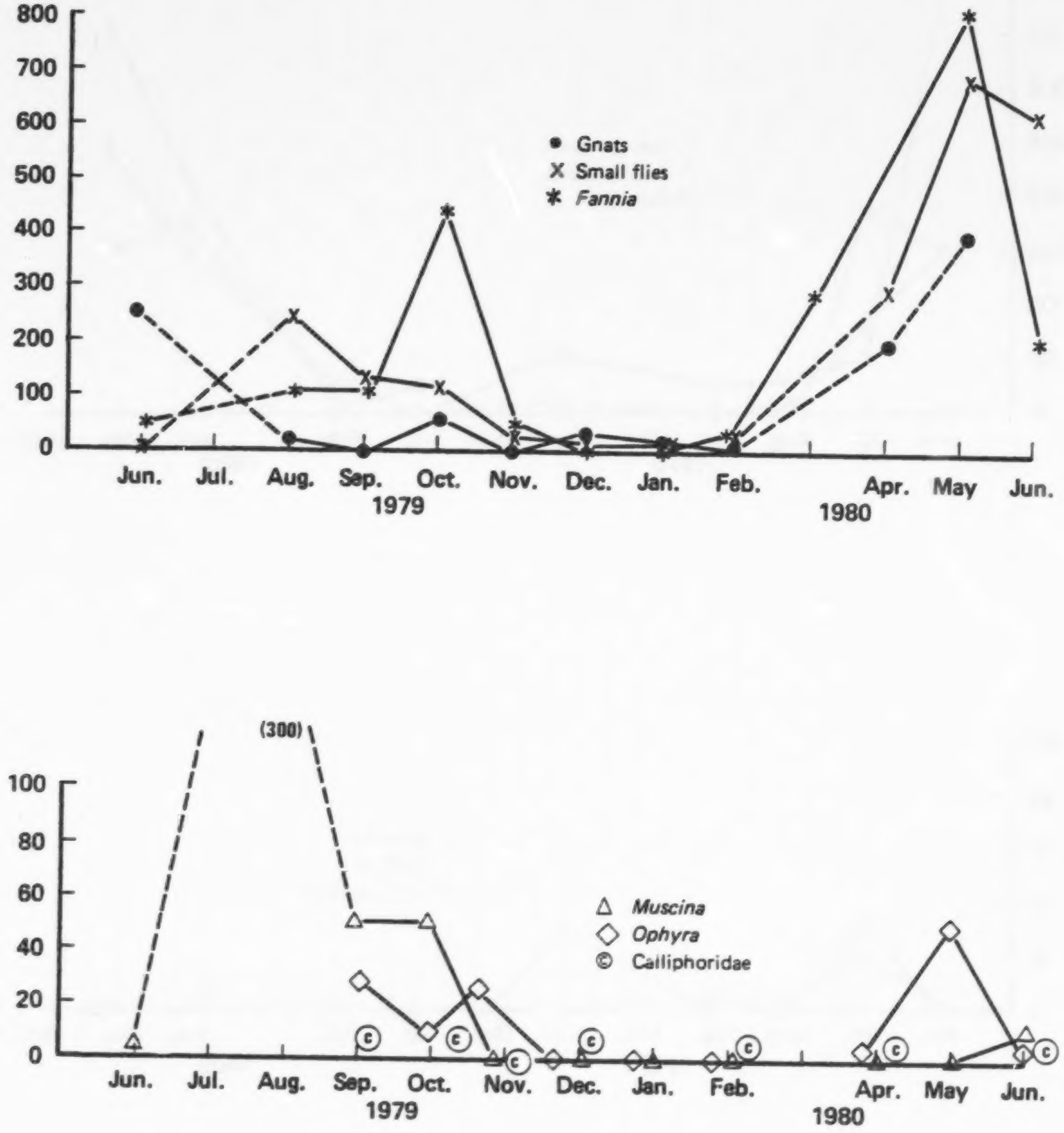
This unit was sampled for mites on the toilet seat 12 times, of which 4 swabs showed only one mite each in August, October, November, and December 1979.

### TABLE 1 UNIT M: MICROBIOLOGICAL DATA

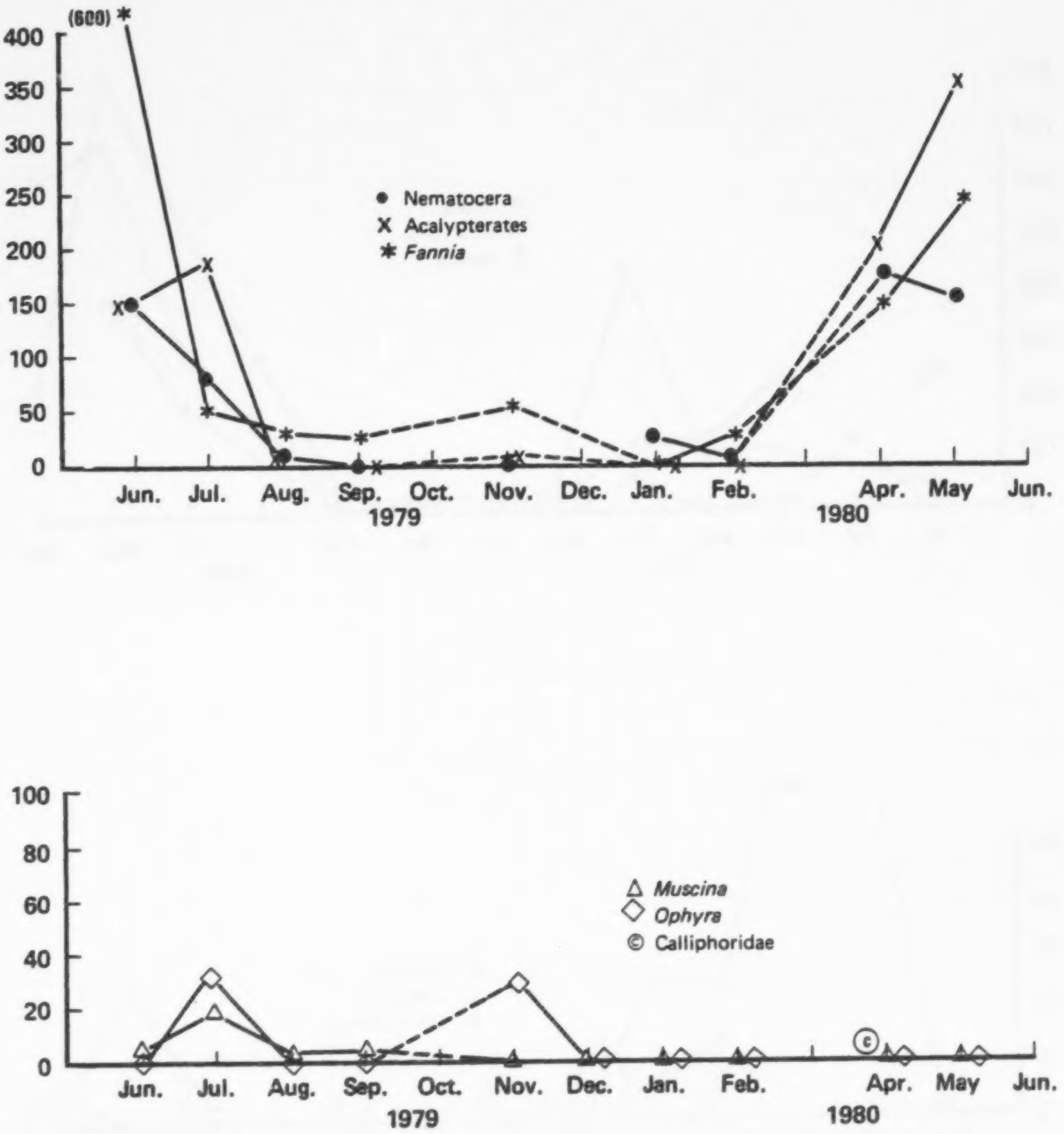
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | F | $4.9 \times 10^6$ | $7.9 \times 10^4$ | Proteus mirabilis<br>Citrobacter freundii<br>Citrobacter diversus | Appearance: Appears to be dry compost. One mite egg. No known human parasites found. | None Isolated | |
| September 1979 | F | $3.1 \times 10^7$ | $7.9 \times 10^6$ | Enterobacter cloacae<br>Escherichia coli<br>Citrobacter freundii<br>Yersinia enterocolitica | Appearance: Appears to be dry compost. Mite eggs and one questionable shriveled larva seen. No known human parasites found. | None Isolated | |
| October 1979 | F | $\geqslant 2.4 \times 10^9$ | $\geqslant 2.4 \times 10^9$ | Enterobacter hafniae<br>Escherichia coli | Appears to be dry compost with dry feces. One larva seen, probably free-living. No known human parasites found. | None Isolated | |
| December 1979 | C | $\geqslant 2.4 \times 10^9$ | $2.3 \times 10^7$ | | | | 1 month storage |
| January 1980 | C | $1.3 \times 10^9$ | $1.3 \times 10^9$ | Proteus mirabilis<br>Citrobacter freundii<br>Proteus morganii<br>Proteus vulgaris | Two-month-old Finished Compost-- Appearance: Appears to be fresh feces. Occasional larvae, probably free-living. No known human pathogens found. | None Isolated | 2 months storage |
| February 1980 | C | $2.4 \times 10^9$ | $7.9 \times 10^8$ | | | | 3 months storage |
| April 1980 | C | $2.2 \times 10^7$ | $4.9 \times 10^6$ | | | | 5 months storage |
| **Finished (C)** | | | | | | | |
| Geometric Mean | | $1.9 \times 10^8$ | $1.0 \times 10^8$ | | | | |
| Range | | $10^7 - 10^9$ | $10^6 - 10^9$ | | | | |
| N = | | 3 | 4 | | | | |

### TABLE 2 UNIT M: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | 8.3 | 66 | 34 | 84 | 16 |
| September 1979 | F | 8.4 | 61 | 39 | 76 | 24 |
| October 1979 | F | 7.5 | 51 | 49 | 75 | 25 |
| December 1979 | C | 6.5 | 76 | 24 | 83 | 17 |
| January 1980 | C | 6.9 | 73 | 27 | 23 | 77 |
| February 1980 | C | 7.5 | 73 | 27 | 80 | 20 |
| April 1980 | C | 7.7 | 53 | 47 | 79 | 21 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 7.1 | 68 | 30 | 59 | 27 |
| Range | | 6.5 – 7.7 | 53 – 76 | 24 – 27 | 23 – 83 | 17 – 77 |
| N = | | 4 | 4 | 4 | 4 | 4 |



GRAPH 1 UNIT M: IN-USE CHAMBER

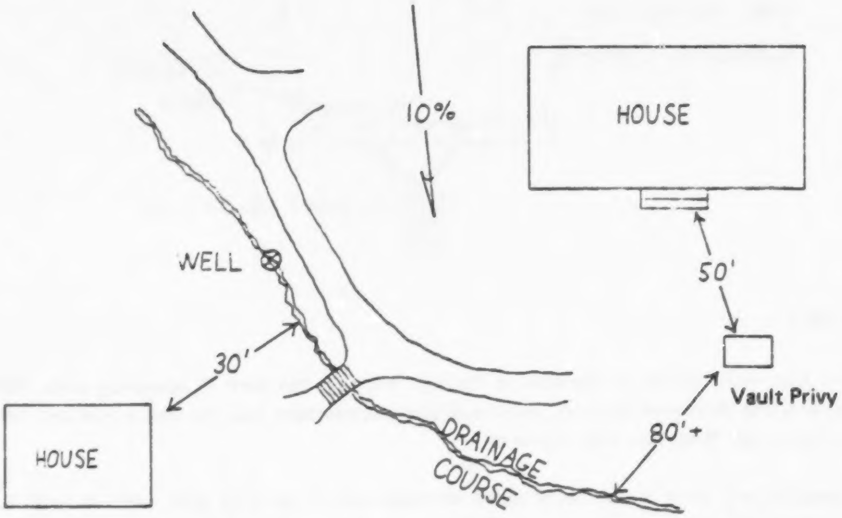


GRAPH 2 UNIT M: AGING CHAMBER

## UNIT N

### SITE DESCRIPTION

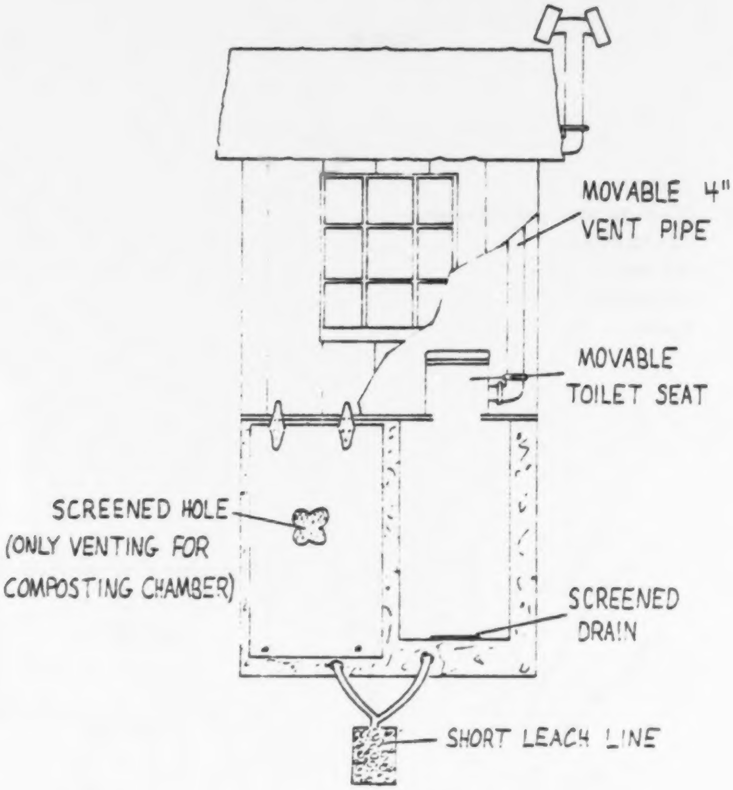
Climate: Coastal
Depth to Groundwater: 4′–5′ perched groundwater
Soil Percolation: 45–60 min./in.
Depth to Bedrock: > 4 feet
Slope: 10 percent
Lot Size: 6 acres



### UNIT DESIGN

Type: Vault privy
Size: Two vaults @ 34" x 42" x 36"
Construction Material: Poured-in-place concrete with wood structure above
Ventilation:
- Fresh side vented with 4" metal pipe connected to the toilet seat riser with a rain cap on top
- Aging chamber vented by screened door hole

Other:
- Vaults completely separate
- Drainage system around privy
- Screen inside vent pipe
- Toilet seat seal
- Plastic membrane wrap around vaults



## SERVICE HISTORY

One of the first vault toilets in Mendocino County, the unit has been in operation since 1975. During the study two adults and one child used the unit. Urine addition was sporadic, i.e., the man would use the unit occasionally for urination purposes. Their diet was vegetarian.

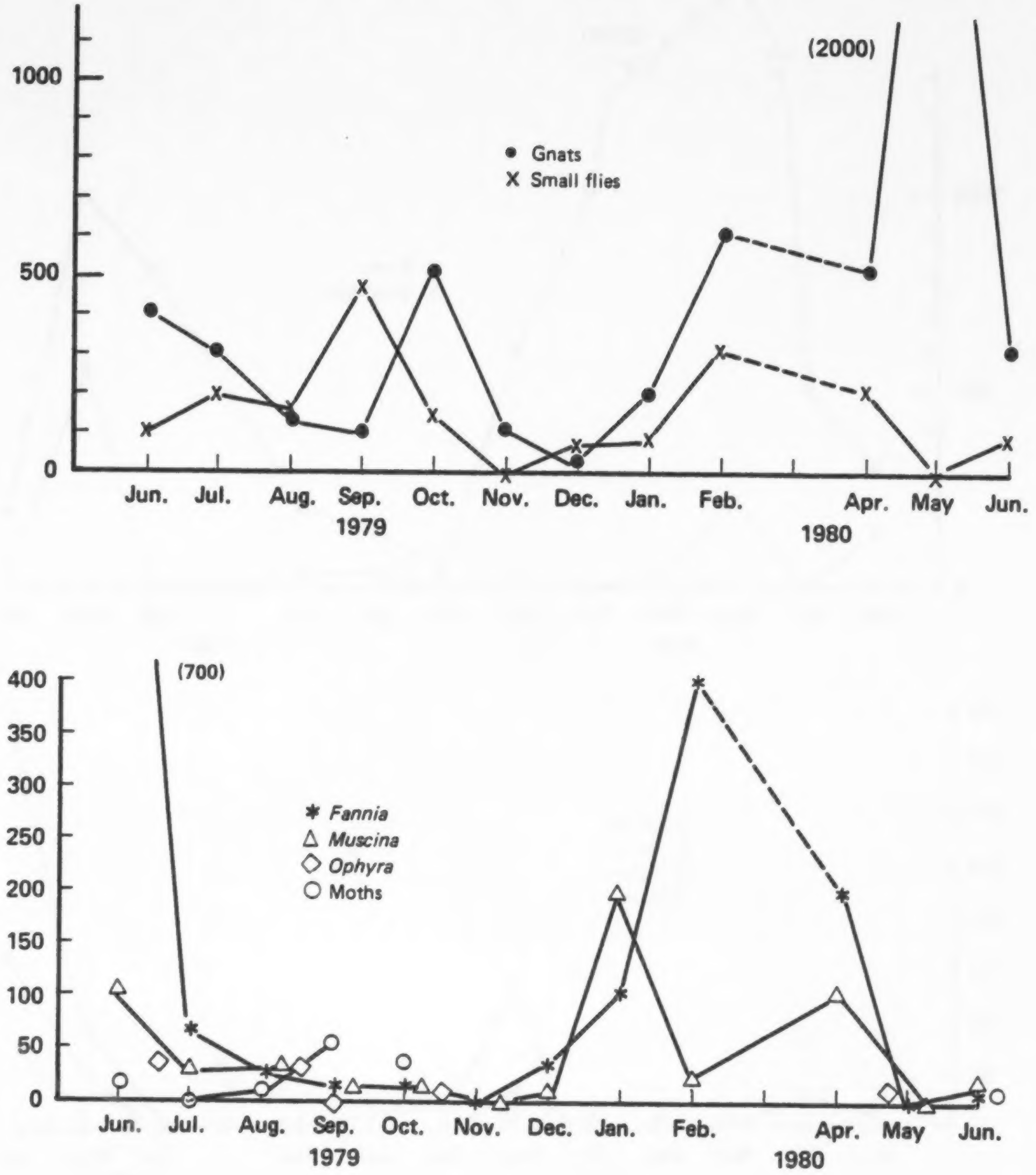
Adding straw to start the pile, the users added redwood and fir sawdust after each use until November 1979 after which they used fir sawdust. In December 1979, the sawdust contained a small amount of horse manure. In addition, ashes were added approximately every other month. The piles were turned once a month and each chamber was filled for six months and allowed to "age" for another six. At the end of the year cycle the material was added to garden compost and then buried around fruit trees.

## HIGHLIGHTS

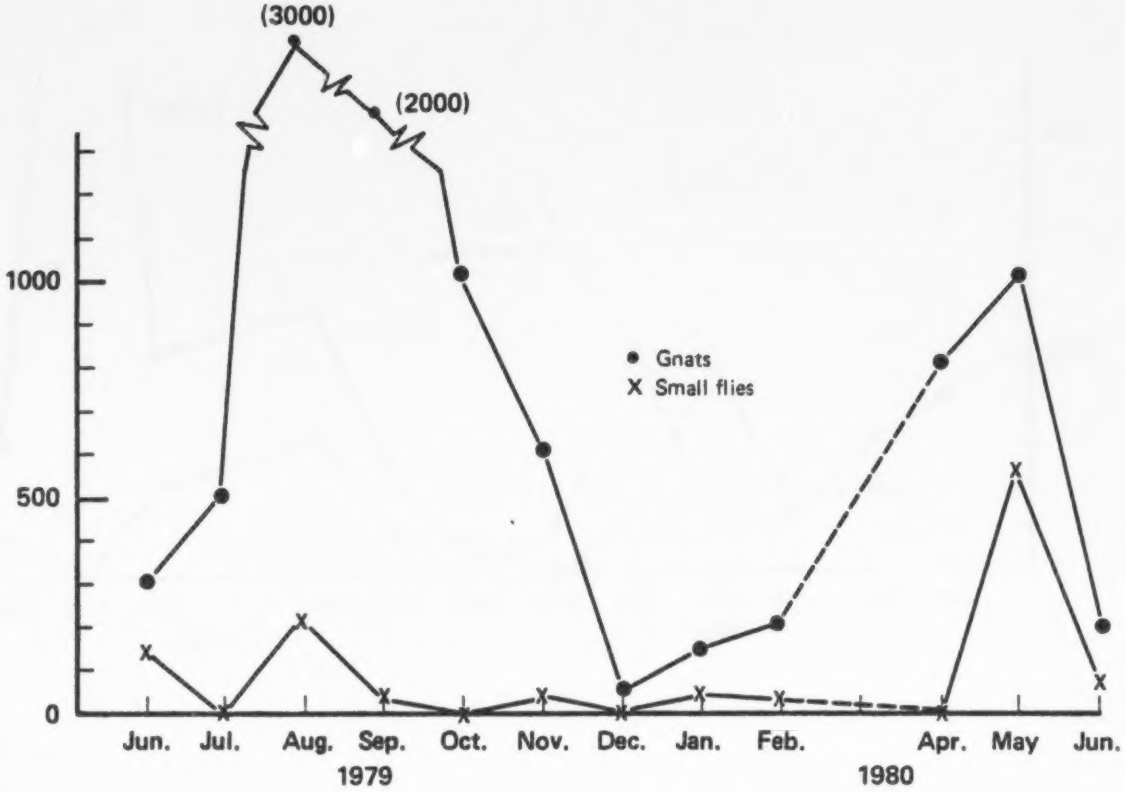
The unit was installed in the side of the hill and showed groundwater infiltration during the winter months. The owner installed screened drains in the chamber floor and connected the drains to a ½" pipe leach field for subsurface disposal.

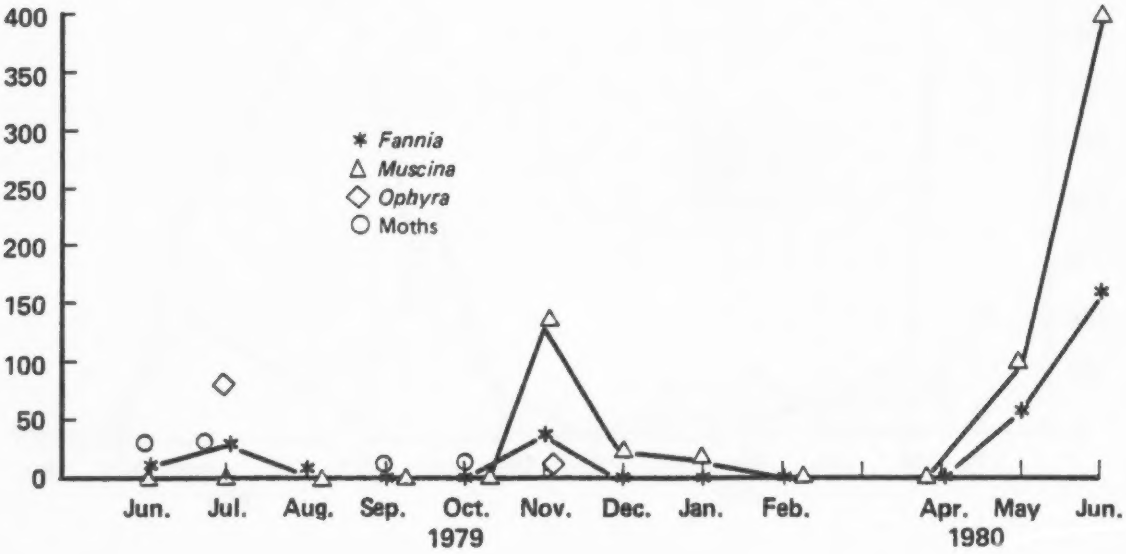
Addition of wood ash to the pile was described by the owners as being very effective in controlling household flies. Odors were also described as controllable. Frogs resided in the aging chamber from August through October.

Mites were found on 4 out of 11 swabs taken from the toilet seat (1 each in May and November 1979, and 2 in January, and 8 in February 1980).



GRAPH 1 UNIT N: IN-USE CHAMBER





GRAPH 2 AGING CHAMBER

## TABLE 1 UNIT N: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | $2.2 \times 10^6$ | $1.4 \times 10^6$ | | | |
| September 1979 | C | $2.3 \times 10^7$ | $2.3 \times 10^7$ | | | |
| October 1979 | C | $4.9 \times 10^7$ | $3.3 \times 10^7$ | | | |
| November 1979 | C | $>2.4 \times 10^9$ | $>2.4 \times 10^9$ | | | |
| December 1979 | C | $1.3 \times 10^8$ | $3.3 \times 10^7$ | | | |
| January 1980 | C | $1.1 \times 10^9$ | $4.9 \times 10^6$ | | | |
| February 1980 | C | $7.9 \times 10^8$ | $3.3 \times 10^8$ | | | |
| April 1980 | C | $2.3 \times 10^8$ | $2.3 \times 10^6$ | | | |
| June 1980 | C | $7.0 \times 10^8$ | $2.3 \times 10^8$ | | Finished Compost—Appearance: Finished compost. Moderate number of larvae, probably free-living. Few very small eggs, probably free-living. No known human parasites found. | |
| **Finished (C)** | | | | | | |
| Geometric Mean | | $9.1 \times 10^7$ | $2.7 \times 10^7$ | | | |
| Range | | $10^6 - 10^9$ | $10^6 - 10^8$ | | | |
| N = | | 8 | 8 | | | |

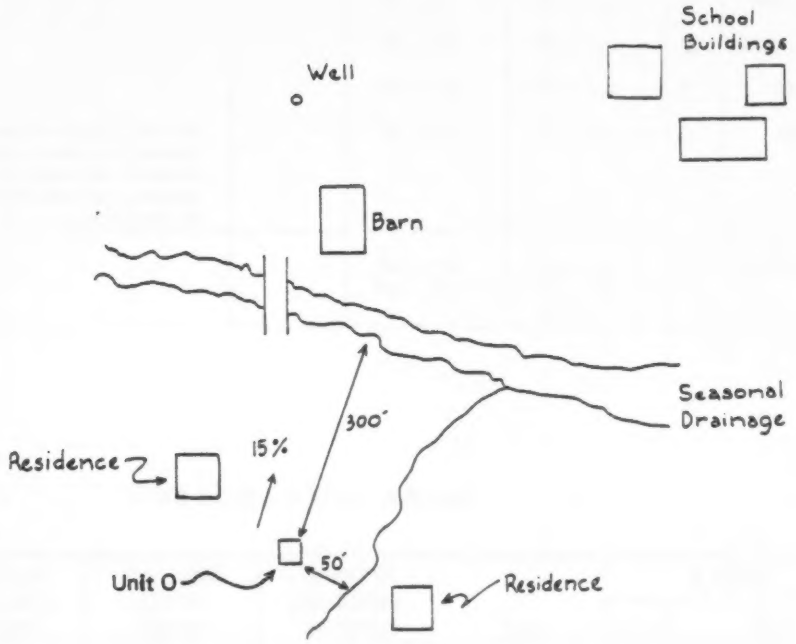
## TABLE 2 UNIT N: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 8.3 | 67 | 33 | 61 | 39 |
| September 1979 | C | 8.2 | 53 | 47 | 28 | 72 |
| October 1979 | C | 7.8 | 64 | 36 | 51 | 49 |
| November 1979 | C | 7.4 | 72 | 28 | 67 | 33 |
| December 1979 | C | 7.2 | 37 | 63 | 18 | 82 |
| January 1980 | C | 7.8 | 67 | 33 | 25 | 75 |
| February 1980 | C | 7.3 | 63 | 37 | 71 | 29 |
| April 1980 | C | 7.9 | 67 | 33 | 82 | 18 |
| May 1980 | C | 7.6 | 72 | 29 | 79 | 21 |
| June 1980 | C | 7.6 | 65 | 35 | 68 | 32 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 7.7 | 62 | 36 | 49 | 40 |
| Range | | 7.2 – 8.3 | 37 – 72 | 29 – 63 | 25 – 82 | 18 – 82 |
| N = | | 10 | 10 | 10 | 10 | 10 |

# UNIT O

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | > 5 feet |
| Soil Percolation: | < 60 min./in. |
| Depth to Bedrock: | > 4 feet |
| Slope: | 15 percent |
| Lot Size: | 5 acres |


School Buildings
Well
Barn
Seasonal Drainage
300'
15%
Residence
Unit O
50'
Residence

## UNIT DESIGN

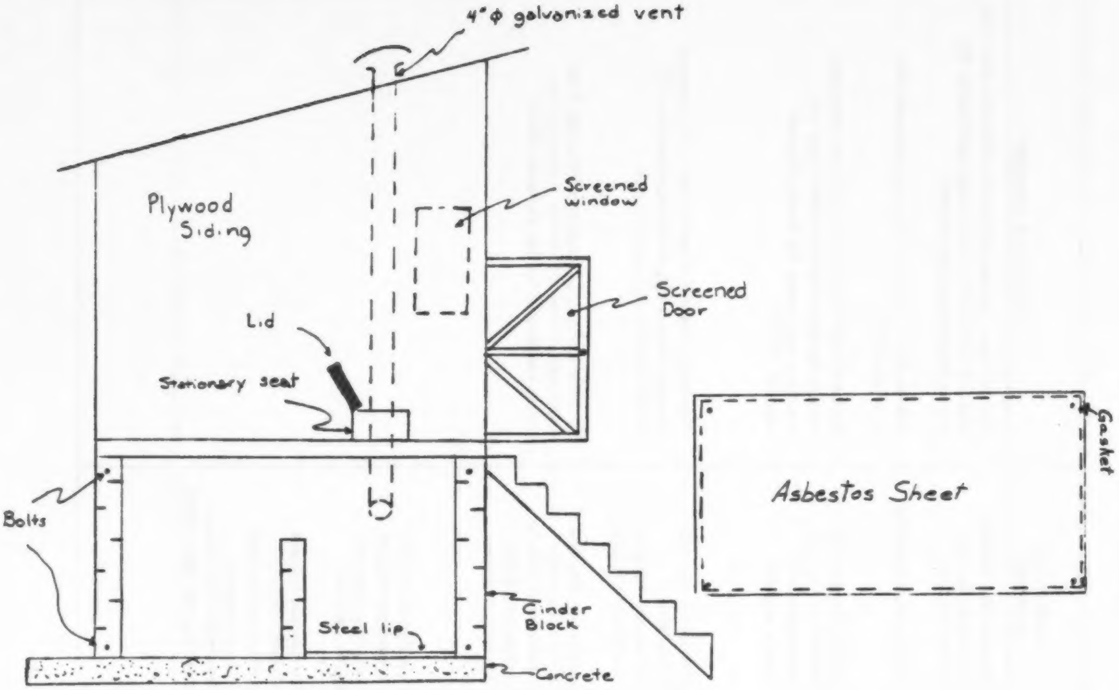
Type: Vault composting privy

Size: Two vaults @ 33" x 41" each

Construction Material:
- Cinderblock vaults with concrete foundation and steel lip along vault opening
- Short divider wall between vaults
- Asbestos vault door attached with ten wing nuts
- Plywood siding for structure with screen door and window

Ventilation:
- No holes or inlets in service hatch or vault walls for incoming air
- Outlet hole in cinderblock of fresh chamber to 4" galvanized metal pipe running inside wall to 1' above roof line
- Top capped and screened

Other:
- No insulation
- Permanent toilet seat structure with seal


4" ϕ galvanized vent
Plywood Siding
Screened window
Screened Door
Lid
Stationary seat
Bolts
Steel lip
Cinder Block
Concrete
Asbestos Sheet
Gasket

## SERVICE HISTORY

Installed in early 1978, the unit accommodated three users (two adults and one child). The actual use may be closer to one person full time because the users usually spent their days away from the unit.

The owners applied a bed of sawdust to start up each chamber, and a combination of fir and redwood sawdust was added after each use. The toilet seat was kept closed after each use. The owners turned the piles once a month with a large shovel. Because the toilet seat was stationary, the "finished" material from the aging chamber was first removed for disposal and then the newer wastes were moved into the aging chamber. The owners performed this rotation about once a year, burying the "finished" material in an orchard.

## HIGHLIGHTS

Liquid buildup, odors, and insects were not reported by the users as problems for this unit. The composting chamber was always dry. The sanitarians reported no signs of rodents. The users reported one small problem of where to put the vault door when off.

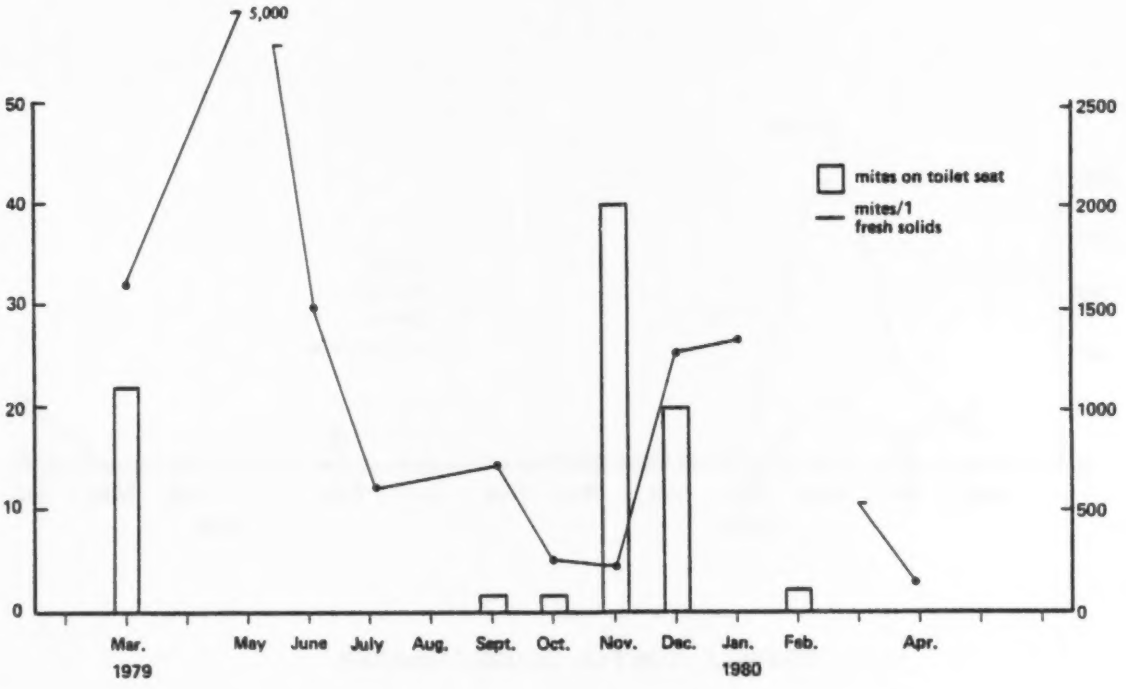
In addition to the flies found on the fly tapes as shown on the following graph, moths were found on all the tapes counted from both chambers. Moth numbers ranged from 100 to 300 in June through November 1979; and 1 to 2 per tape thereafter until an increase in the last month of sampling (June 1980).

## TABLE 1 UNIT O: MICROBIOLOGICAL DATA

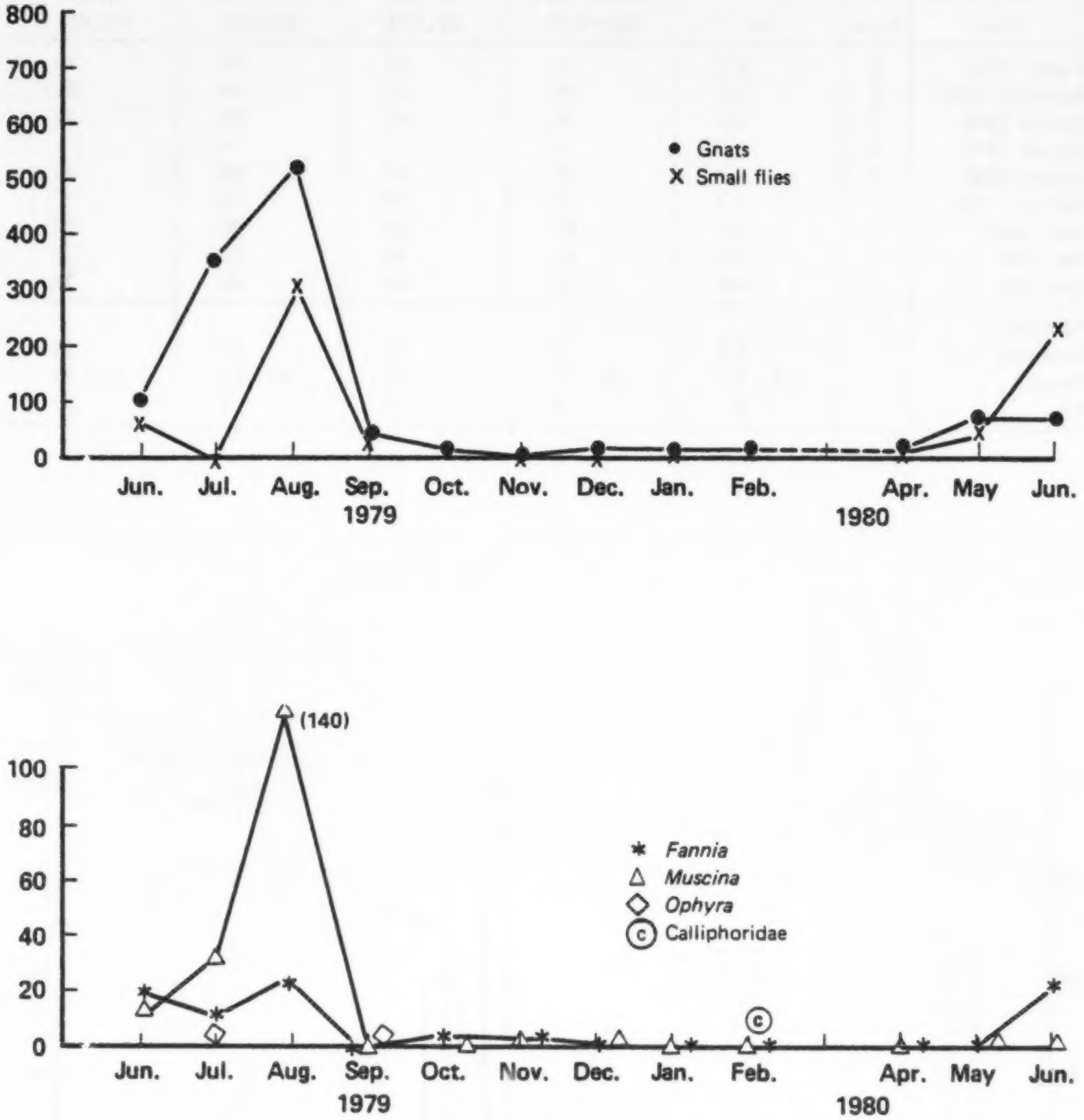
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | $1.7 \times 10^3$ | $7.0 \times 10^2$ | Enterobacter hafniae<br>Citrobacter freundii<br>Proteus vulgaris | Appearance: Appears to be dry compost. Very few eggs and larvae seen—not human pathogens. No known human parasites found. | None Isolated |
| September 1979 | C | $4.6 \times 10^3$ | $5.0 \times 10^2$ | Yersinia enterocolitica | Appearance: Appears to be dry compost. No parasites found. | None Isolated |
| October 1979 | F | $9.2 \times 10^9$ | $9.2 \times 10^9$ | Salmonella arizonae<br>Citrobacter freundii<br>Escherichia coli<br>Proteus vulgaris | Appears to be feces coated with dry compost. Few larvae and two thin-shelled eggs seen, probably free-living. No known human parasites found. | None Isolated |
| October 1979 | C | $2.2 \times 10^3$ | $2.0 \times 10^2$ | | | |
| January 1980 | C | $1.1 \times 10^5$ | $<2.0 \times 10^2$ | Citrobacter freundii<br>Hafnia alvei<br>Providencia rettgeri<br>Enterobacter cloacae | Finished Compost—Appearance: Dry finished compost. Small egg, not human parasite. No known human pathogens found. | None Isolated |
| February 1980 | C | $4.9 \times 10^5$ | $2.3 \times 10^6$ | Citrobacter freundii<br>Providencia rettgeri<br>Enterobacter cloacae<br>Serratia marescens<br>Klebsiella ozaenae | Finished compost. Occasional mite egg. Few small eggs, occasional larvae, probably free-living. No known human parasites found. | |
| April 1980 | C | $7.0 \times 10^7$ | $3.3 \times 10^6$ | | | |
| May 1980 | C | $2.3 \times 10^7$ | $3.3 \times 10^5$ | Providencia rettgeri<br>Citrobacter freundii<br>Klebsiella oxytoca<br>Escherichia coli | | |
| June 1980 | C | $1.3 \times 10^5$ | $5.0 \times 10^2$ | Providencia rettgeri<br>Proteus mirabilis<br>Citrobacter freundii<br>Proteus vulgaris<br>Klebsiella pneumoniae<br>Enterobacter aglomerans | | |
| **Finished (C)**<br>Geometric Mean<br>Range<br>N = | | <br>$1.9 \times 10^5$<br>$10^3 - 10^7$<br>8 | <br>$8.0 \times 10^3$<br>$10^2 - 10^6$<br>8 | | | |

## TABLE 2 UNIT O: SOLID DATA

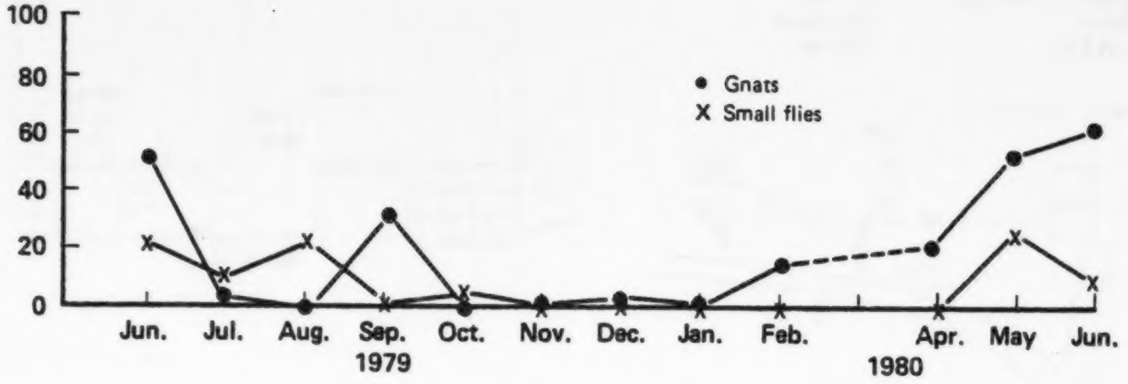
| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 5.3 | 30 | 70 | 82 | 18 |
| September 1979 | C | 5.6 | 29 | 72 | 70 | 30 |
| October 1979 | F | 6.7 | 36 | 64 | 68 | 32 |
| October 1979 | C | 6.5 | – | – | – | – |
| January 1980 | C | 5.4 | 53 | 47 | 68 | 32 |
| February 1980 | C | 5.7 | 74 | 26 | 23 | 77 |
| April 1980 | C | 6.3 | 62 | 38 | 90 | 10 |
| May 1980 | C | 5.2 | 61 | 39 | 73 | 27 |
| June 1980 | C | 4.8 | 55 | 45 | 85 | 15 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 5.6 | 49 | 46 | 65 | 25 |
| Range | | 4.8 – 6.5 | 29 – 74 | 26 – 72 | 23 – 90 | 10 – 77 |
| N = | | 8 | 7 | 7 | 7 | 7 |

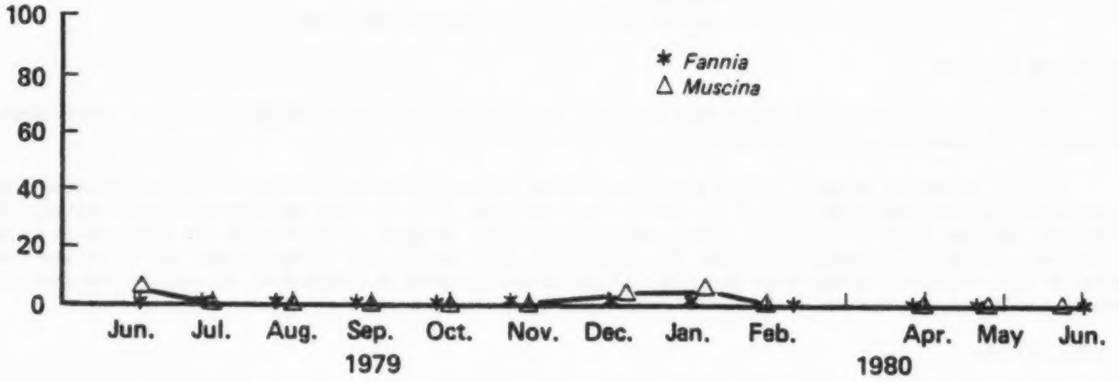


GRAPH 1 OCCURRENCE OF MITES



GRAPH 2 UNIT O: IN-USE CHAMBER



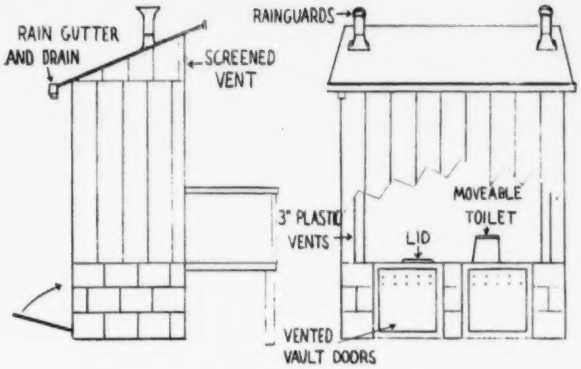


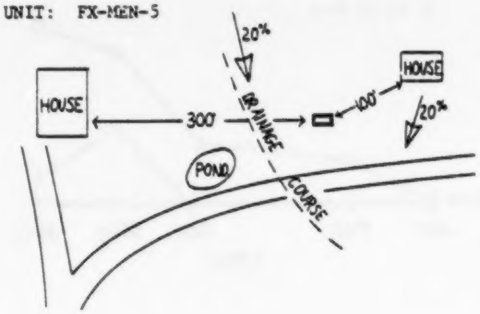
GRAPH 3 AGING CHAMBER

## UNIT P

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater | 150 feet |
| Soil Percolation: | < 60 min./in. |
| Depth to Bedrock: | 3.5 feet |
| Slope: | 20 percent |
| Lot Size: | 10 acres |





### UNIT DESIGN

| | |
|---|---|
| Type: | Vault composting privy |
| Size: | 36" x 36" x 36" – two vaults |
| Ventilation: | • 1¼" screened holes in service hatches and small screened inlet above door<br>• Each vault's separate outlet through 4" plastic (ABS), screened at bottom<br>• Vents 24" above roof, capped at top |
| Other: | • No insulation<br>• Cap fits over toilet seat<br>• Insecticide strips in both chambers<br>• A specially marked pitchfork to turn and remove wastes |

### SERVICE HISTORY

This well-built unit was installed in March–April 1977. One adult used it throughout the study with an additional user for three to four months in the winter.

Start-up procedure included placing 4" of straw on the floor and installing a no-pest strip in the chamber. The users added approximately two cups of fir sawdust after each use. The toilet seat was kept closed when not in use. The fresh pile was turned every month. After a six-month period, "finished" material from the aging chamber was tilled into the ground beneath fruit trees. Also during the study period, the owner decided not to remove the material from the aging chamber when the six-month period was complete, but instead left the material and used the chamber as if emptying had occurred. Users often urinated away from the unit.

### HIGHLIGHTS

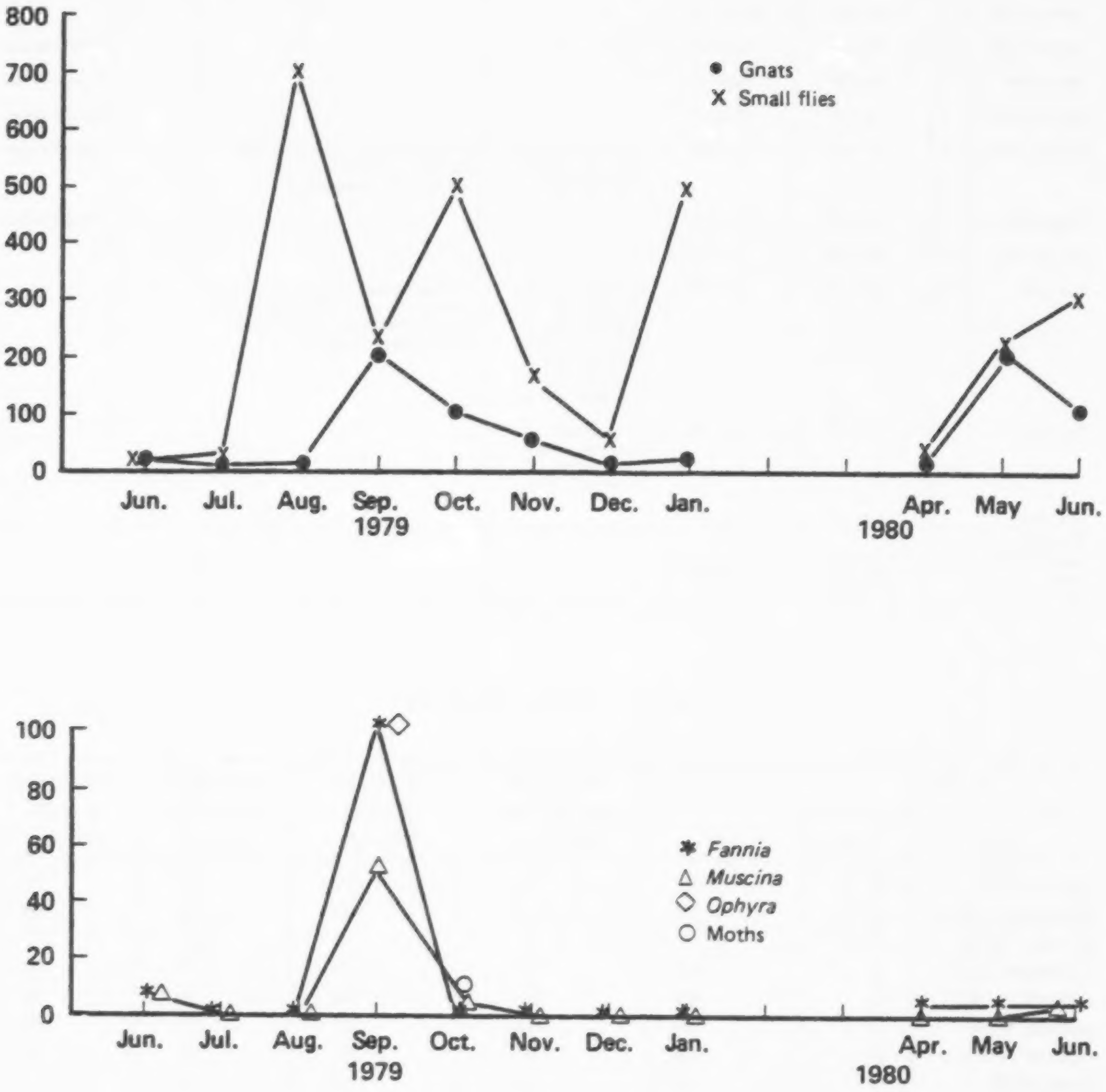
There were no major liquid buildup, odor, or insect problems reported by users or sanitarians. A slight odor before mixing time, or when kitchen wastes were added, was reported. Users stopped adding kitchen wastes soon after start-up. Urination away from the unit was more a matter of convenience than necessity since users reported the condition of the pile as generally too dry. No rodent problem existed. The insecticide strip was reported as being very effective. This unit had by far the fewest numbers of muscid flies (*Fannia*, *Muscina*, and *Ophyra*) of all the five units of this type which were studied, which may be attributable to the well-constructed access doors which were tightly sealed. In addition to the fly counts shown on Tables 4 and 5, 20 calliphoridae were found on the fresh chamber tape in May 1980 indicating a short-lived infestation of this vault.

## TABLE 1 UNIT P: MICROBIOLOGICAL DATA

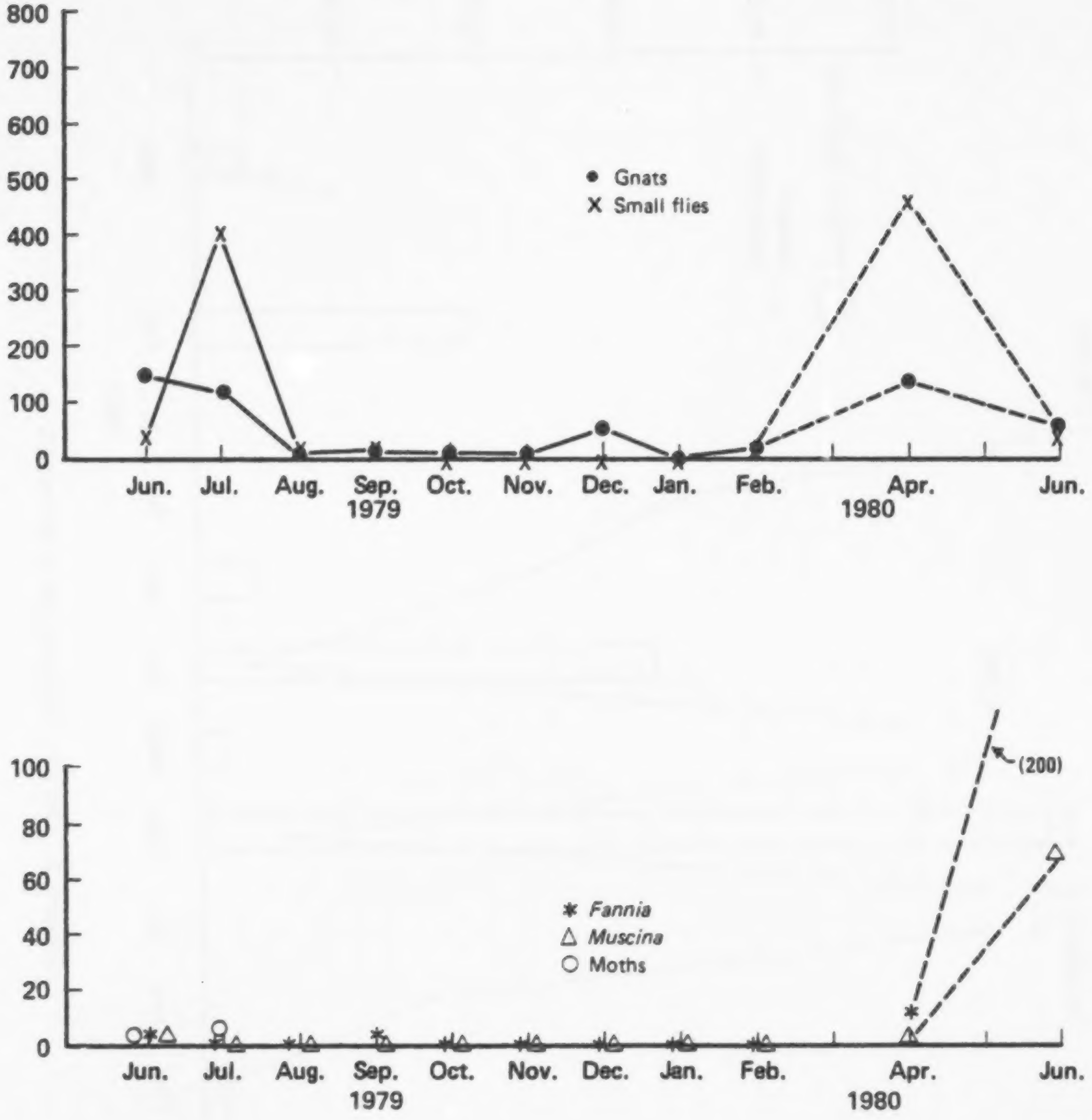
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $2.2 \times 10^6$ | $6.3 \times 10^5$ | | | | |
| September 1979 | C | $8.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | |
| September 1979 | C | $7.9 \times 10^7$ | $2.3 \times 10^4$ | | | | 0 month storage |
| October 1979 | C | $3.3 \times 10^7$ | $1.3 \times 10^7$ | | | | 1 month storage |
| November 1979 | C | $4.9 \times 10^5$ | $2.3 \times 10^5$ | | | | 2 month storage |
| December 1979 | C | $1.1 \times 10^3$ | $2.0 \times 10^2$ | Yersinia enterocolitica<br>Citrobacter freundii<br>Klebsiella ozaenae | Finished Compost—Appearance: Few live larvae, probably free-living. No known human parasites found. | | 3 month storage |
| January 1980 | C | $1.4 \times 10^3$ | $<2.0 \times 10^2$ | | | | 4 month storage |
| February 1980 | C | $2.4 \times 10^9$ | $2.4 \times 10^9$ | | | | |
| April 1980 | C | $5.4 \times 10^9$ | $2.3 \times 10^8$ | Enterobacter cloacae<br>Escherichia coli<br>Klebsiella ozaenae<br>Citrobacter freundii<br>Proteus mirabilis<br>Proteus vulgaris<br>Providencia rettgeri | Finished Compost—Appearance: Finished compost. Occasional mite egg, occasional larvae probably free-living. No known human parasites found. | | |
| May 1980 | C | $2.2 \times 10^6$ | $1.1 \times 10^6$ | Proteus morganii<br>Citrobacter freundii<br>Escherichia coli<br>Providencia rettgeri | | | |
| June 1980 | C | $2.1 \times 10^5$ | $1.3 \times 10^3$ | | | | |
| **Finished (C)** | | | | | | | |
| Geometric Mean | | $1.3 \times 10^6$ | $1.4 \times 10^5$ | | | | |
| Range | | $10^9 - 10^2$ | $10^9 - <10^2$ | | | | |
| N = | | 11 | 11 | | | | |

## TABLE 2 UNIT P: SOLID DATA

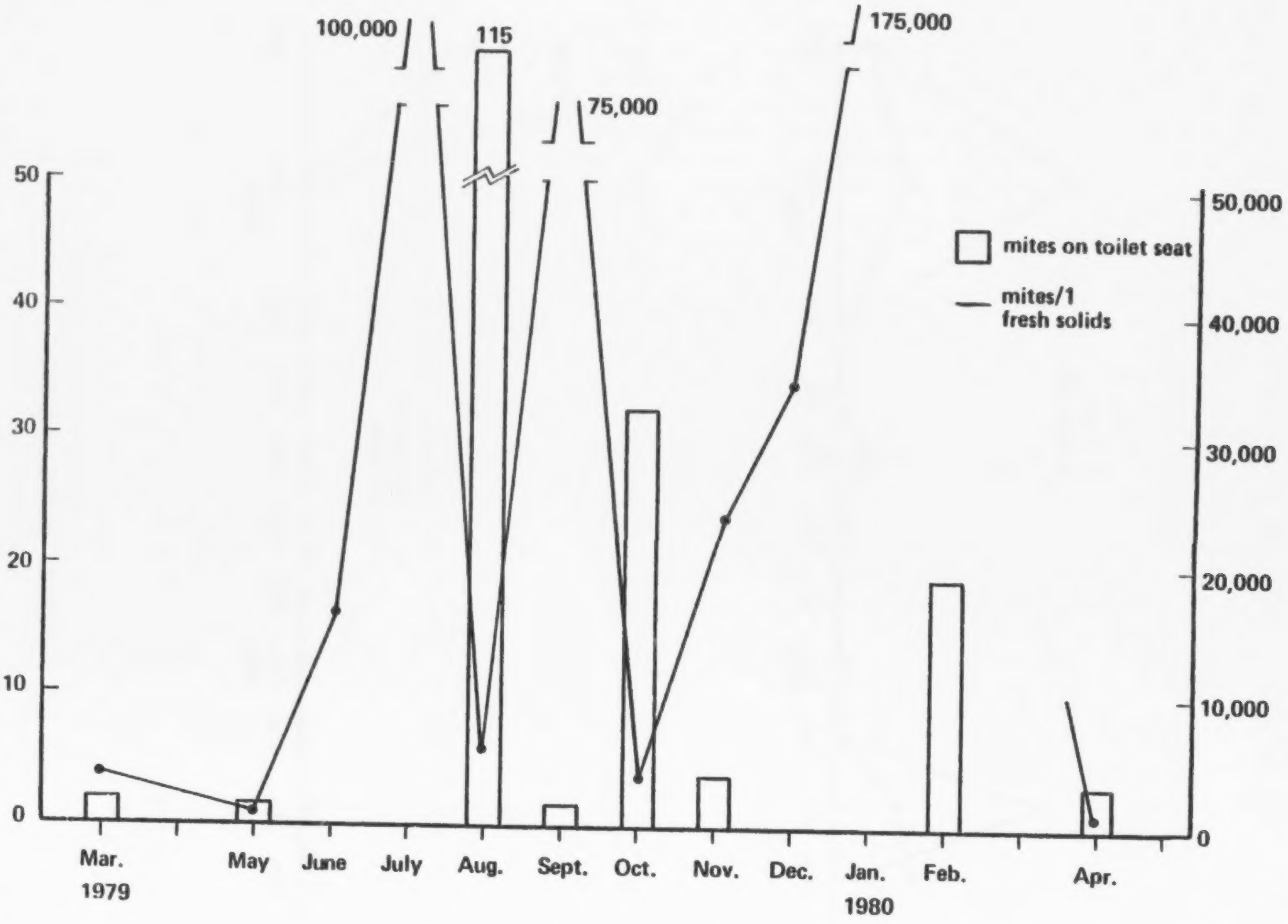
| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 5.0 | 29 | 72 | 86 | 14 |
| September 1979 | C | 6.4 | 40 | 60 | 66 | 34 |
| October 1979 | C | 5.2 | 21 | 79 | 67 | 33 |
| November 1979 | C | 4.8 | 20 | 80 | 71 | 29 |
| December 1979 | C | 4.4 | 57 | 43 | 86 | 14 |
| January 1980 | C | 5.4 | 62 | 39 | 32 | 69 |
| February 1980 | C | 6.2 | 39 | 61 | 90 | 10 |
| April 1980 | C | 6.3 | 60 | 40 | 93 | 7 |
| May 1980 | C | 4.3 | 64 | 36 | 77 | 23 |
| June 1980 | C | 4.3 | 63 | 37 | 89 | 11 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 5.2 | 42 | 52 | 73 | 19 |
| Range | | 4.3 – 6.4 | 21 – 64 | 36 – 80 | 32 – 93 | 7 – 68 |
| N = | | 10 | 10 | 10 | 10 | 10 |



GRAPH 1 IN-USE CHAMBER



GRAPH 2 AGING CHAMBER

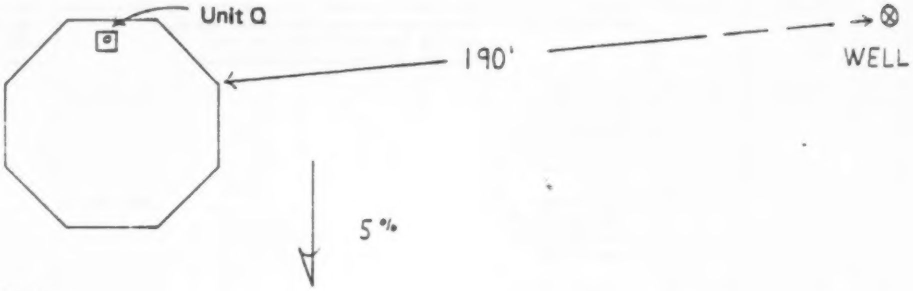


GRAPH 3 UNIT P: OCCURRENCE OF MITES

## UNIT Q

### SITE DESCRIPTION

Climate: Mountain
Depth to Groundwater: 10 feet
Soil Percolation: 30 min./in.
Drinking Water Source: Private well 190 feet from house
Slope: 5 percent
Lot Size: 1.4 acres



### UNIT DESIGN

Type: Box-like humus with topping bar, Mullbank
Ventilation:
- Built-in electric fan
- Vent pipe to roof

Insulation: Lower portion in insulated compartment below floor level
Other: Screened bathroom and vent pipe

### SERVICE HISTORY

The unit was installed in fall 1976 and had one user with occasional guests (one–two guests/two–three days per month) from February 1979 to November 1979. From November 1979 to June 1980 two people with a baby used the unit. The first user described her diet as vegetarian while the present users included a lot of meat in theirs.

The first user added wood chips occasionally to the pile and removed the finished compost every three–four months, burying it in the yard.

### HIGHLIGHTS

There was some liquid buildup due to rain entering the vent. The toilet heater coils were frequently left unplugged. A fan was installed in the vent stack and used constantly. Toilet paper would sometimes show up in the finished tray indicating a short retention time. The user described the finished material as dry.

The second users added two handfuls of sawdust to their system daily and ran the fan continuously. The finished tray was emptied every three to four weeks with a small unmarked shovel and disposed of through on-site burial.

The users reported a liquid buildup problem and drained their unit as advised by the dealer who originally installed the unit. Odors and insects were reported to be problems. The users sprayed with Raid insecticide spray and hung sticky tapes in the bathroom. In general, the second users who were renting the place were dissatisfied with the unit operation, especially any activity involving manipulation of the wastes.

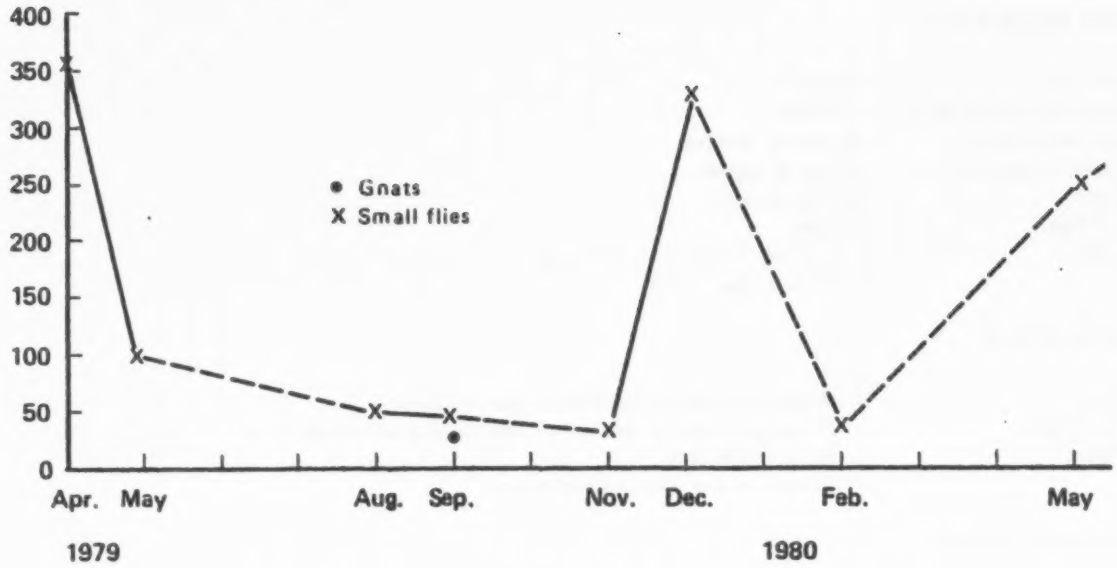
One sample of the liquid contained in the finished tray was analyzed and results show values similar to geometric mean values reported for Unit R.

## TABLE 1 UNIT Q: MICROBIOLOGICAL DATA

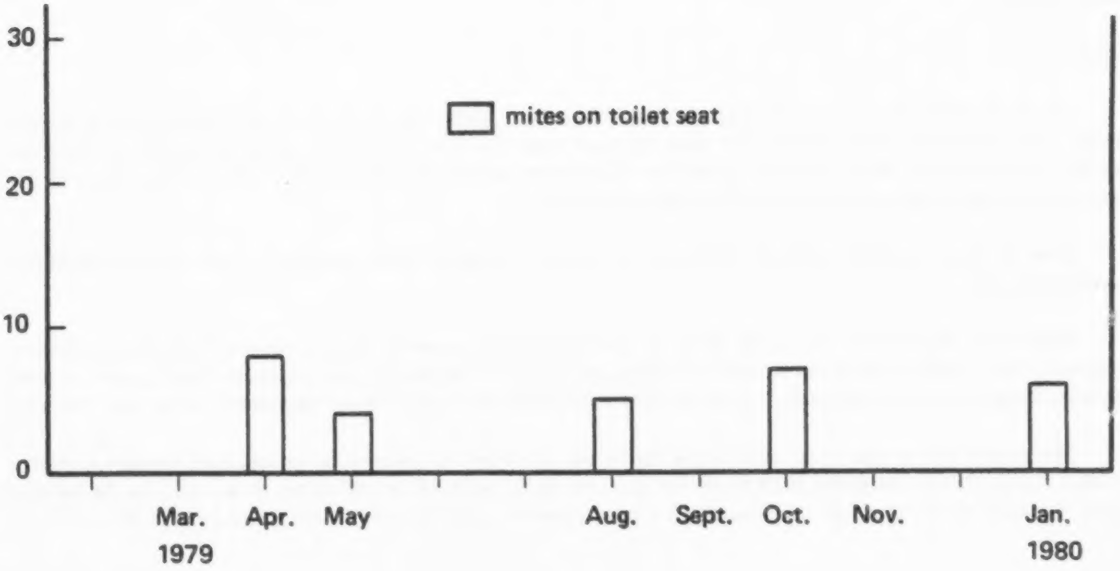
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $2.3 \times 10^7$ | $1.3 \times 10^4$ | | | | |
| October 1979 | C | $5.4 \times 10^9$ | $7.9 \times 10^6$ | | | | |
| November 1979 | F | $1.3 \times 10^7$ | $1.7 \times 10^6$ | Citrobacter freundii<br>Providencia rettgeri | Appearance: Fresh feces mixed with sawdust. Few live larvae, few thin-shelled eggs, too small for hookworm, probably free-living. No known human pathogens found. | None Isolated | |
| November 1979 | C | $4.7 \times 10^7$ | $7.0 \times 10^5$ | | | | |
| December 1979 | F | $7.9 \times 10^7$ | $1.3 \times 10^6$ | Citrobacter freundii<br>Providencia rettgeri | Fresh Feces—Appearance: Fresh feces mixed with sawdust. Moderate number of live larvae, probably free-living. Few thin-shelled eggs, not human pathogens. No known human parasites found. | None Isolated | Late November 1979 diagnosed and Viral Hepatitis |
| January 1980 | L | $7.9 \times 10^4$ | $3.3 \times 10^3$ | Proteus vulgaris<br>Proteus mirabilis<br>Citrobacter freundii<br>Providencia rettgeri<br>Proteus morganii | | None Isolated | |
| January 1980 | C | $4.9 \times 10^4$ | $2.3 \times 10^3$ | Proteus mirabilis<br>Citrobacter freundii<br>Providencia rettgeri<br>Proteus vulgaris | | None Isolated | |
| March 1980 | C | $3.3 \times 10^5$ | $<2.0 \times 10^2$ | Providencia rettgeri<br>Citrobacter freundii<br>Proteus vulgaris | | | |
| May 1980 | C | $7.9 \times 10^6$ | $7.9 \times 10^3$ | | | | |
| June 1980 | L | $3.5 \times 10^3$ | $<2.0 \times 10$ | | | | |
| Finished (C) | | | | | | | |
| Geometric Mean | | $9.5 \times 10^6$ | $4.2 \times 10^4$ | | | | |
| Range | | $10^4 - 10^9$ | $<10 - 10^6$ | | | | |
| N = | | 6 | 6 | | | | |

## TABLE 2 UNIT Q: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 6.6 | 60 | 40 | 51 | 49 |
| October 1979 | C | 7.8 | 70 | 30 | 63 | 37 |
| November 1979 | F | 6.6 | 75 | 25 | 76 | 24 |
| November 1979 | C | 8.1 | 73 | 27 | 68 | 32 |
| December 1979 | F | SAMPLE REFUSED | | | | |
| January 1980 | C | 6.9 | 76 | 24 | 61 | 39 |
| March 1980 | C | 8.9 | 64 | 36 | 53 | 47 |
| May 1980 | C | 8.3 | 70 | 30 | 33 | 67 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.67 | 69 | 31 | 53 | 44 |
| Range | | 6.6 – 8.9 | 60 – 76 | 24 – 40 | 51 – 68 | 32 – 67 |
| N = | | 6 | 6 | 6 | 6 | 6 |



GRAPH 1 OCCURRENCE OF FLYING INSECTS



GRAPH 2 OCCURENCE OF MITES

## UNIT R

### SITE DESCRIPTION

Climate: Coastal
Depth to Groundwater: > 10 feet
Soil Percolation: 45 min./in. and less
Depth to Bedrock: 10 feet or greater
Slope: 10–15 percent
Lot Size: 40 acres
Other:
- Located in bathroom (in house)
- Pit privy also on lot

### UNIT DESIGN

Type: Box-like humus toilet with topping bar, Mullbank
Ventilation:
- 4" insulated pipe, 3' above roof with turbine fan on top

Other:
- Seal on toilet seat
- Screens on vent pipe and bathroom

### SERVICE HISTORY

The unit was installed in June 1979, and four people used the unit full time with occasional visitor use (approximately one/month). User diet was described as normal with some meat.

The users added ¼ cup of peat moss after each use to their system. The toilet seat was kept closed when not in use and the electric ventilation fan was run continuously. The pile was spread out mechanically after each use. Though the waste contents were never removed for disposal, the user planned to dispose the material in a pit privy located on-site.

### HIGHLIGHTS

The users reported a liquid buildup problem which they attempted to control with increased heat from a heater in the bathroom during winter and more dry peat moss. On one occasion, an increased number of users was directly responsible for liquid buildup in the unit. Sanitarians usually reported liquid in the finished tray and the users generally described the condition of the pile as too moist.

Three or four sprayings in March 1980 with pyrethrum insecticide were described by the users as ineffective against small flies.

Odors were reported by users only when the fan failed due to power outages or when certain wind conditions prevailed. Other owner complaints included a broken collar around the handle, and a sporadic heating coil. A toilet seat replacement could not be found. A problem with visitors not closing the lid was resolved by a sign near the unit.

One sample of the peat moss used by the family was submitted for parasite screenings in an attempt to clarify whether the previously identified hookworm-like eggs and larvae were being introduced to the unit by the bulking agent. However, the commercial peat moss contained no organisms and the question remained unresolved.

## TABLE 1 UNIT R: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | F | $1.3 \times 10^8$ | $7.9 \times 10^7$ | Citrobacter freundii<br>Escherichia coli | Appearance: Looks like fresh feces. Viable eggs and larvae found resembling human hookworm, slightly atypical. Conclusion after consultation: Probably not human hookworm. | None isolated |
| August 1979 | L | $<2.0 \times 10^4$ | $<2.0 \times 10^4$ | | | |
| September 1979 | M | $3.1 \times 10^3$ | $<2.0 \times 10^2$ | Citrobacter freundii<br>Enterobacter cloacae | Appearance: Appears to be fresh feces. Eggs and larvae seen, similar to what was seen in first sample. Conclusion after consultation: Probably not human hookworm. | None isolated |
| September 1979 | L | $8.0 \times 10$ | $2.0 \times 10$ | | | |
| November 1979 | C | $2.0 \times 10^2$ | $2.0 \times 10^2$ | Proteus morganii<br>Proteus rettgeri | Appearance: Black, finished compost. Few dead larvae, probably free-living. No known human parasites found. | |
| November 1979 | L | $7.9 \times 10^2$ | $7.9 \times 10^3$ | | | |
| December 1979 | C | $7.0 \times 10^2$ | $1.7 \times 10^2$ | | Finished Compost—Appearance: Black, wet dirt occasional larvae, probably free-living. No known human parasites found. | |
| December 1979 | L | $1.4 \times 10^4$ | $3.3 \times 10^3$ | Citrobacter freundii<br>Proteus morganii<br>Proteus rettgeri | | |
| January 1980 | C | $1.3 \times 10^3$ | $<2.0 \times 10^2$ | Proteus morganii | Finished Compost—Appearance: Black wet compost. Few to moderate number of larvae, probably free-living. No known human parasites found. | |
| January 1980 | L | $3.3 \times 10^3$ | $7.9 \times 10^2$ | Proteus morganii<br>Proteus mirabilis<br>Escherichia coli | | |
| February 1980 | C | $2.8 \times 10^6$ | $7.0 \times 10^6$ | | Finished compost. Occasional larvae, probably free-living, few cyst-like structures. No known human parasites found. | |
| February 1980 | L | $6.3 \times 10^4$ | $1.4 \times 10^3$ | Proteus mirabilis<br>Proteus morganii<br>Providencia rettgeri | Leachate finished tray appearance brown liquid. Many larvae, probably free-living, many small cyst-like structures probably free-living. No known human parasites found. | None isolated |
| March 1980 | C | $3.5 \times 10^4$ | $<2.0 \times 10^2$ | | | |
| March 1980 | L | $9.4 \times 10^3$ | $1.3 \times 10^2$ | | | |
| April 1980 | C | $8.4 \times 10^4$ | $2.3 \times 10^3$ | | | |
| April 1980 | L | $8.4 \times 10^3$ | $1.4 \times 10^2$ | | | |
| May 1980 | L | $7.9 \times 10^5$ | $4.9 \times 10^2$ | | | |
| May 1980 | C | $1.3 \times 10^6$ | $<2.0 \times 10^2$ | | | |
| June 1980 | L | $1.4 \times 10^4$ | $7.0 \times 10$ | | | |
| **Liquid (L)** | | | | | | |
| Geometric Mean | | $1.1 \times 10^4$ | $3.3 \times 10^2$ | | | |
| Range | | $10 - 10^5$ | $10 - 10^4$ | | | |
| N = | | 10 | 10 | | | |
| **Finished (C)** | | | | | | |
| Geometric Mean | | $2.1 \times 10^4$ | $1.2 \times 10^3$ | | | |
| Range | | $10^2 - 10^6$ | $<10^2 - 10^6$ | | | |
| N = | | 7 | 7 | | | |

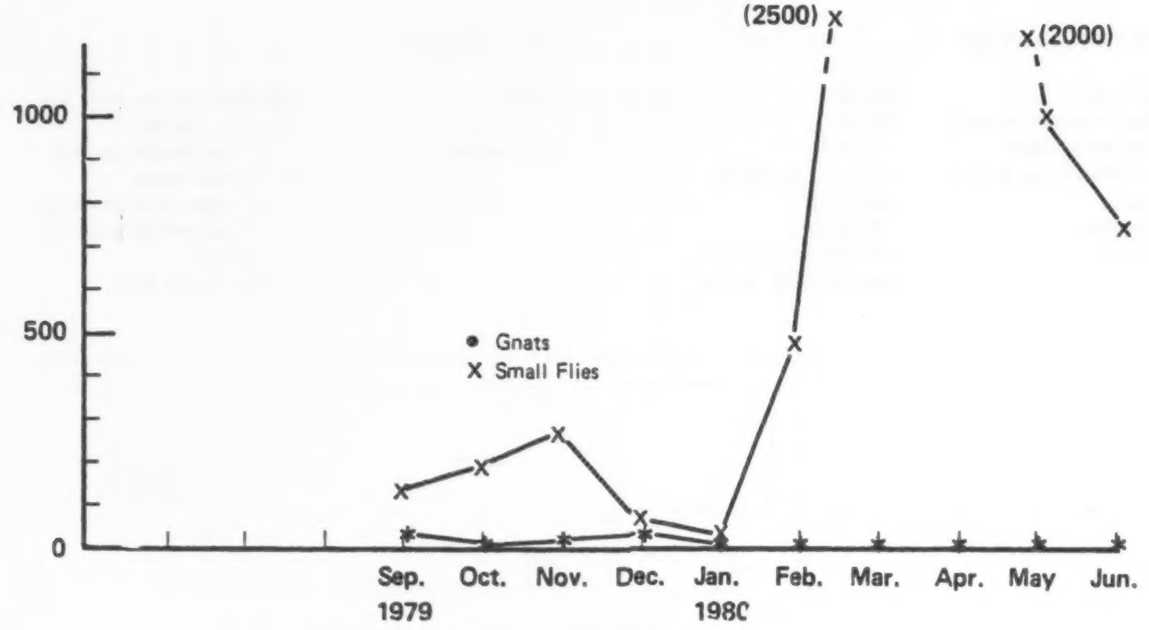
## TABLE 2 UNIT R: SOLID DATA

| SAMPLE | | | | | | |
|---|---|---|---|---|---|---|
| Date | Type | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
| August 1979 | F | 7.8 | 72 | 28 | 82 | – |
| September 1979 | F | 8.8 | 74 | 27 | 80 | – |
| November 1979 | C | 8.2 | 46 | 54 | 18 | 82 |
| February 1980 | C | 8.4 | 61 | 39 | 23 | 77 |
| January 1980 | C | 8.0 | 66 | 34 | 83 | 17 |
| March 1980 | C | 6.8 | 23 | 77 | 21 | 79 |
| April 1980 | C | 8.3 | 59 | 41 | 20 | 86 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 7.9 | 48 | 44 | 27 | 58 |
| Range | | 6.8 – 8.4 | 23 – 66 | 34 – 77 | 18 – 83 | 17 – 82 |
| N = | | 5 | 5 | 5 | 5 | 5 |

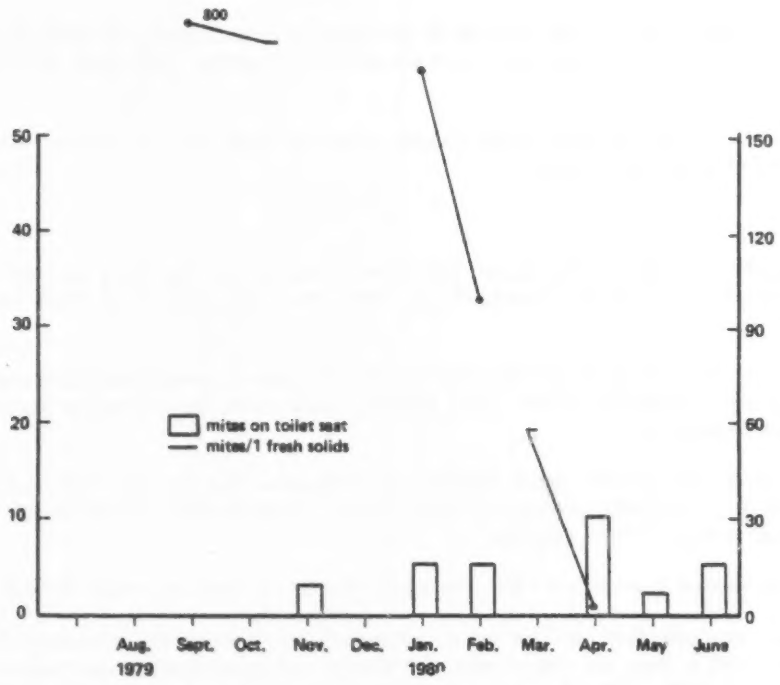
## TABLE 3 UNIT R: LIQUID DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC µmhos/cm |
| August 1979 | L | 7.9 | – | $1.0 \times 10^3$ | $2.4 \times 10^4$ | $9.0 \times 10^4$ | $1.1 \times 10^3$ | $6.7 - 10^4$ | 23.7 | $1.2 \times 10^5$ |
| September 1979 | L | 7.1 | – | $1.5 \times 10^3$ | $6.0 \times 10^4$ | $2.8 \times 10^5$ | $8.8 \times 10^4$ | $1.9 \times 10^4$ | 212.6 | $2.9 \times 10^5$ |
| October 1979 | L | 7.3 | – | LE | $2.6 \times 10^4$ | $1.4 \times 10^5$ | $6.0 \times 10^2$ | $6.4 \times 10^3$ | 204 | $4.6 \times 10^4$ |
| November 1979 | L | 8.2 | – | $1.2 \times 10^3$ | $1.4 \times 10^4$ | $6.2 \times 10^4$ | $4.6 \times 10^3$ | $4.0 \times 10^3$ | $< 0.4$ | $9.1 \times 10^4$ |
| February 1980 | L | 8.0 | 2.3 | 910 | $1.1 \times 10^4$ | $5.3 \times 10^4$ | $7.1 \times 10^3$ | $3.7 \times 10^3$ | $< 0.1$ | $5.1 \times 10^4$ |
| March 1980 | L | 8.2 | 0.5 | 570 | $5.7 \times 10^3$ | $2.2 \times 10^4$ | $5.9 \times 10^2$ | $3.1 \times 10^3$ | $< 10$ | $2.5 \times 10^4$ |
| April 1980 | L | 8.6 | – | 890 | $4.5 \times 10^3$ | $1.8 \times 10^4$ | $9.0 \times 10^2$ | $5.2 \times 10^3$ | 8.4 | $3.6 \times 10^4$ |
| **Liquid (L)** | | | | | | | | | | |
| Geometric Mean | | 7.8 | – | – | $5.8 \times 10^3$ | $6.3 \times 10^4$ | $1.8 \times 10^3$ | $7.9 \times 10^3$ | 8.6 | $2.1 \times 10^4$ |
| Range | | 7.1 – 8.6 | 0.5 – 2.3 | $10^2 - 10^3$ | $10^3 - 10^4$ | $10^4 - 10^5$ | $10^2 - 10^4$ | $10^3 - 10^4$ | 0.1 – 212 | $10^4 - 10^5$ |
| N = | | 8 | 2 | 8 | 8 | 8 | 8 | 7 | 7 | 8 |

LE = Laboratory Error



GRAPH 1 OCCURRENCE OF FLYING INSECTS



GRAPH 2 OCCURRENCE OF MITES

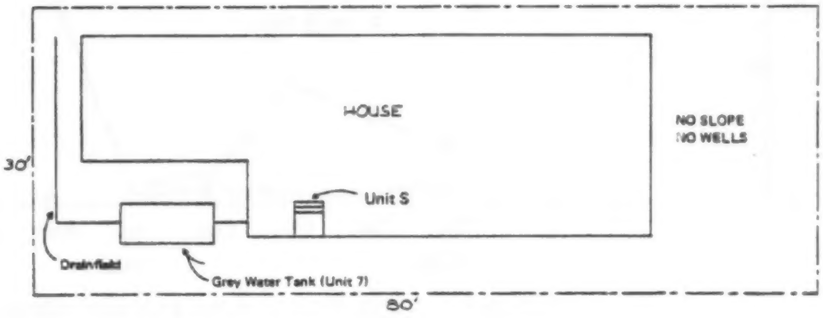
# UNIT S

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 3½'–4' |
| Soil Percolation: | 1 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 0 percent |
| Lot Size: | 1/20 acre |
| Other: | Unit located in bathroom of rental home |

## UNIT DESIGN

| | |
|---|---|
| Type: | Box-like humus with topping bar, Mullbank |
| Ventilation: | • 4" plastic pipe to roof<br>• Outside house<br>• 4" pipe surrounded by 8" galvanized pipe (insulated)<br>• Fan inside vent |



## SERVICE HISTORY

Installed in October 1978, the unit was used by two groups of tenants during the study. From February 1979 to September 1979 there were two–three full-time users and from December 1979 there were two–four full-time users.

Nothing was used to start the unit nor was material added during use. The pile was never mixed or turned and the pan was never emptied during the study.

## HIGHLIGHTS

Both groups of tenants did not like the unit and refused to maintain it. The first group used the fan and heater located in the bathroom continuously through August 1979 and a small amount of liquid was reported in the finished tray.

After August the fan and heater were disconnected when the tenants vacated resulting in a large liquid buildup when the unit was used by clean-up workers. From October to December, the unit was not used; the pile dried out to a cement-like consistency.

When the new tenants arrived, liquid buildup was immediate. The fan and heater were reconnected in February 1980 and used frequently resulting in some decrease in liquid buildup. The heater coil located within the unit appeared to stop working in early February.

The house was vacated in late March 1980. The heating coil and fan were left on and the pile dried out.

Four fly tapes were taken from this unit and the counts indicated a continuing infestation of small flies; 600 in March, 800 in April, 700 in May, and 400 in June. One *Ophyra* and 2 Calliphoridae were taken in June. Mite swab counts began in August 1979 and 6 out of 11 swabs were positive for mites; 1 each in August, October, and February; 4 in December; 60 in April; and 6 in May.

TABLE 1 UNIT S: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | $7.9 \times 10^7$ | $2.2 \times 10^7$ | | | |
| August 1979 | L | $3.3 \times 10^7$ | $1.3 \times 10^7$ | | | |
| September 1979 | C | $1.7 \times 10^6$ | $1.1 \times 10^6$ | | | |
| September 1979 | L | $3.3 \times 10^6$ | $1.1 \times 10^6$ | | | |
| October 1979 | C | $3.3 \times 10^3$ | $1.1 \times 10^3$ | | | |
| November 1979 | C | $3.1 \times 10^5$ | $3.1 \times 10^5$ | | | |
| December 1979 | C | $1.3 \times 10^4$ | $5.0 \times 10^3$ | | | |
| January 1980 | L | $1.3 \times 10^6$ | $1.7 \times 10^5$ | | | |
| February 1980 | L | $7.9 \times 10^4$ | $3.3 \times 10^4$ | Proteus mirabilis<br>Proteus vulgaris<br>Providencia rettgeri<br>Proteus morganii<br>Klebsiella oxytoca | Leachate-emptying tray. Appearance: Brown liquid. Many larvae, probably free-living. Occasional mite, occasional large egg, probably a mite egg. No known human parasites found. | |
| April 1980 | C | $7.9 \times 10^3$ | $3.3 \times 10^3$ | | Finished Compost—Appearance: Hardened soil. Occasional larvae, probably free-living. Occasional adult mite. No known human parasites found. | |
| March 1980 | C | $7.9 \times 10^3$ | $7.9 \times 10^3$ | Proteus mirabilis<br>Proteus vulgaris<br>Providencia rettgeri | Leachate—Appearance: Brown liquid. Many larvae probably free-living. Few free-living ciliates. No known human parasites found. | |
| May 1980 | L | $\geq 2.4 \times 10^9$ | $\geq 2.4 \times 10^9$ | | | |
| June 1980 | L | $1.5 \times 10^3$ | $2.0 \times 10$ | | | |
| Finished (C)<br>Geometric Mean<br>Range<br>N = | | <br>$1.0 \times 10^5$<br>$10^3 - 10^7$<br>7 | <br>$3.8 \times 10^4$<br>$10^3 - 10^7$<br>7 | | | |

TABLE 2 UNIT S: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 7.4 | 68 | 32 | 41 | 59 |
| September 1979 | C | 7.3 | 67 | 33 | 39 | 61 |
| October 1979 | C | 6.8 | 53 | 47 | 37 | 63 |
| November 1979 | C | 8.4 | 39 | 35 | 61 | 39 |
| December 1979 | C | 7.7 | 48 | 52 | 38 | 62 |
| April 1980 | C | 6.0 | 7 | 93 | 33 | 67 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.2 | 38 | 45 | 41 | 58 |
| Range | | 6.0 – 8.4 | 7 – 68 | 32 – 93 | 33 – 61 | 39 – 67 |
| N = | | 6 | 6 | 6 | 6 | 6 |

TABLE 3 UNIT S: LIQUID DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC μmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| August 1979 | L | 7.2 | $7.3 \times 10^3$ | $4.8 \times 10^4$ | $1.9 \times 10^5$ | $8.3 \times 10^3$ | $9.1 \times 10^3$ | – | 128.5 | $1.9 \times 10^5$ |
| September 1979 | L | 6.5 | $>1.0 \times 10^4$ | $5.0 \times 10^4$ | $2.6 \times 10^5$ | $6.6 \times 10^4$ | $1.2 \times 10^4$ | – | 71.5 | $2.5 \times 10^5$ |
| January 1980 | L | 8.5 | $2.1 \times 10^3$ | $8.5 \times 10^3$ | $3.2 \times 10^4$ | $4.0 \times 10^2$ | $3.4 \times 10^3$ | 5.0 | $<10$ | $4.5 \times 10^4$ |
| February 1980 | L | 8.2 | $2.8 \times 10^3$ | $2.0 \times 10^4$ | $8.2 \times 10^4$ | $4.2 \times 10^3$ | $8.5 \times 10^2$ | 1.9 | $<10$ | $1.3 \times 10^5$ |
| March 1980 | L | 79 | $5.3 \times 10^3$ | $2.4 \times 10^4$ | $8.0 \times 10^4$ | $7.7 \times 10^3$ | $4.9 \times 10^3$ | $<1.0$ | $<10$ | $9.5 \times 10^4$ |

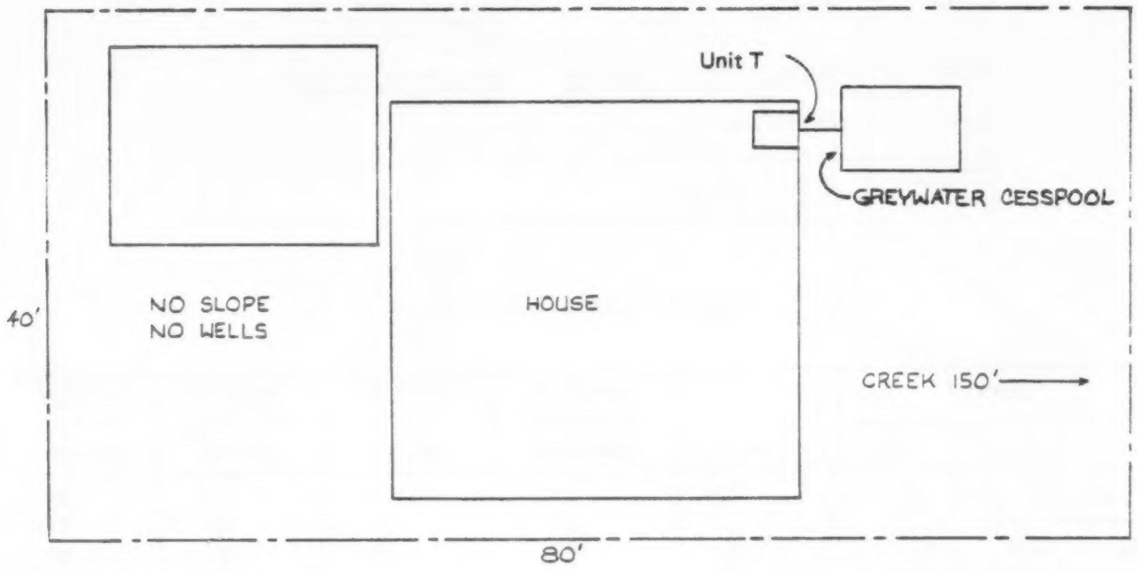
## UNIT T

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 2½'–3' |
| Soil Percolation: | 1 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 0 percent |
| Lot Size: | 1/15 acre |

### UNIT DESIGN

| | |
|---|---|
| Type: | Box-like humus with topping bar |
| Ventilation: | 4" PVC pipe to roof; surrounded by 6" galvanized pipe (insulated) |
| Other: | • Screened vent pipe<br>• No insulation |



### SERVICE HISTORY

Installed in May 1979, the unit joined the study in August. The unit had one half-time user (a tenant) whose diet included some meat.

The unit was started up with peat moss and the user added kitchen refuse, wood ash, and plant cuttings on a weekly basis. The user never turned the pile but inspected it monthly and removed the composted contents every 3–6 months. This material was handled with a specially marked rake and neoprene gloves and was disposed of in an off-site land fill (county septage disposal area).

### HIGHLIGHTS

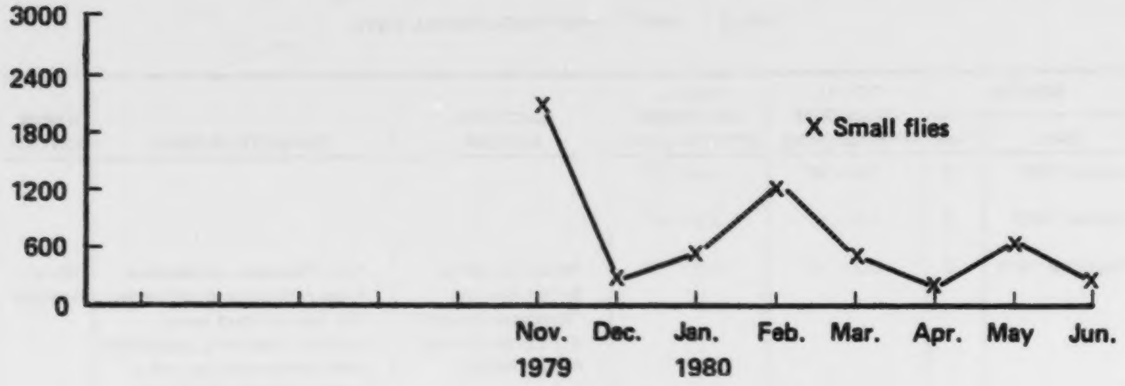
The tenant provided reasonable care for the unit and was able to control all the problems that came up during the study. An increase in flies was noticed when fruit and peels were added. The user sprayed with insecticide in August and later used a pest strip. Odors were reported as a problem only when the fan was not used during use. During the study, the pile dried out, especially around the heating coils and had to be moistened with water spray (one quart per week). The removed waste material was dry and crystal-like.

## TABLE 1 UNIT T: MICROBIOLOGICAL DATA

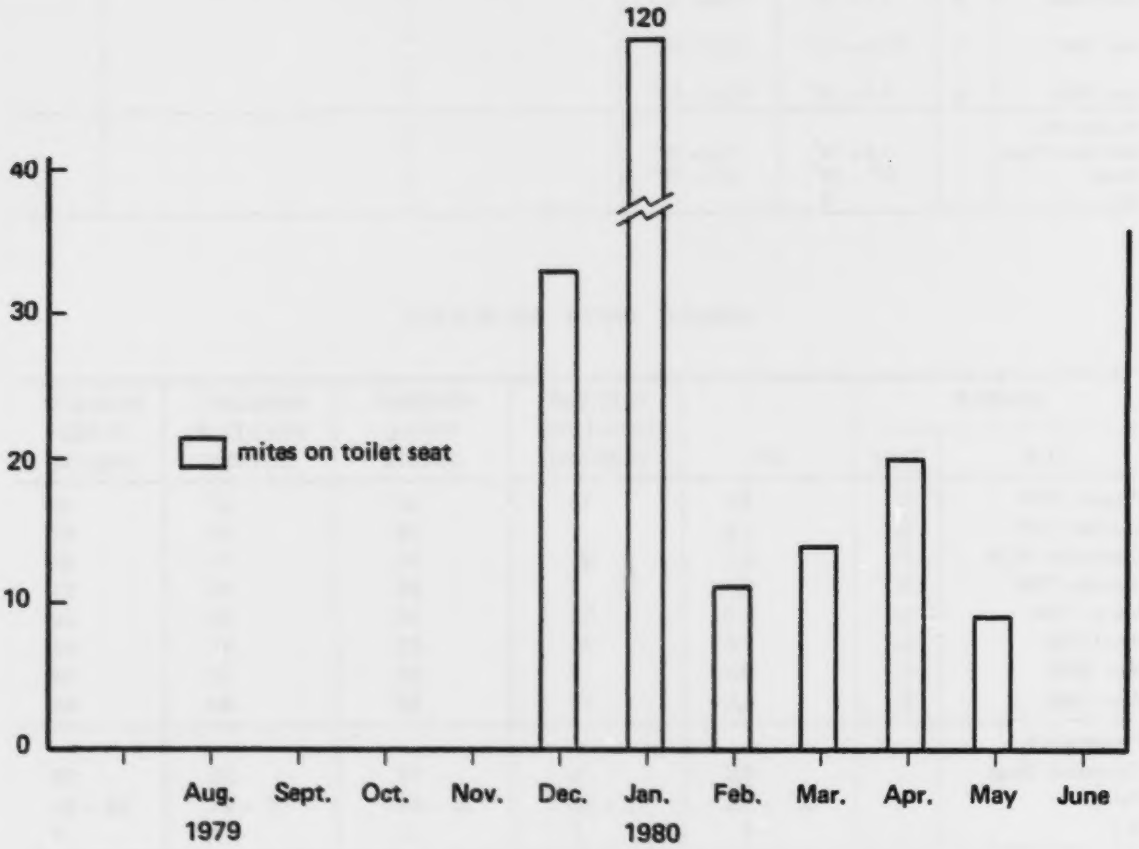
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | $7.9 \times 10^3$ | $4.9 \times 10^3$ | | | |
| October 1979 | C | $1.3 \times 10^3$ | $8.0 \times 10^2$ | | | |
| December 1979 | F | $2.3 \times 10^3$ | $2.0 \times 10^2$ | Proteus mirabilis<br>Escherichia coli<br>Citrobacter freundii<br>Citrobacter freundii<br>Proteus rettgeri | Fresh Compost—Appearance: Feces with dirt and leaf stems. Few live and dead larvae, probably free-living, occasional small thin-shelled egg, not a human pathogen. No known human parasites found. | None Isolated |
| January 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | |
| March 1980 | C | $8.0 \times 10^2$ | $<2.0 \times 10^2$ | | | |
| April 1980 | C | $1.1 \times 10^7$ | $<2.0 \times 10^2$ | | | |
| May 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | |
| June 1980 | C | $1.1 \times 10^3$ | $<2.0 \times 10^2$ | | | |
| Finished (C) | | | | | | |
| Geometric Mean | | $1.0 \times 10^4$ | $2.0 \times 10^3$ | | | |
| Range | | $10^3 - 10^7$ | $10^2 - 10^3$ | | | |
| N = | | 5 | 2 | | | |

## TABLE 2 UNIT T: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 6.4 | 13 | 88 | 27 | 73 |
| October 1979 | C | 7.8 | 5 | 95 | 18 | 82 |
| December 1979 | F | 8.1 | 62 | 38 | 11 | 89 |
| January 1980 | C | 5.1 | 2 | 99 | 19 | 81 |
| March 1980 | C | 6.9 | 12 | 88 | 12 | 88 |
| April 1980 | C | 7.0 | 78 | 22 | 41 | 59 |
| May 1980 | C | 6.3 | 2 | 98 | 12 | 88 |
| June 1980 | C | 6.9 | 18 | 82 | 40 | 60 |
| **Finished (C)** | | | | | | |
| Geometric Mean | | 6.6 | 9 | 75 | 22 | 75 |
| Range | | 5.1 – 7.8 | 2 – 78 | 22 – 99 | 11 – 41 | 59 – 88 |
| N = | | 7 | 7 | 7 | 7 | 7 |



GRAPH 1 OCCURRENCE OF FLYING INSECTS



GRAPH 2 OCCURRENCE OF MITES

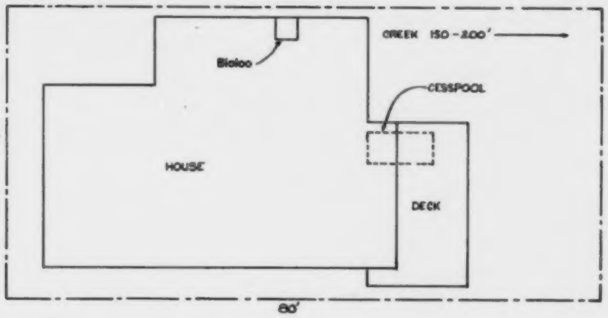
## UNIT U

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 2½'–3' |
| Soil Percolation: | 1 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 0 percent |
| Lot Size: | 1/15 acre |

### UNIT DESIGN

| | |
|---|---|
| Type: | Box-like humus with rotor, Bioloo |
| Ventilation: | • 4" PVC to roof–extends approximately 3' above roof<br>• Electric fan in vent–it is surrounded by 12" galvanized pipe with insulation<br>• Wind rotor-type cap on top |
| Other: | Toilet seat seal |



### SERVICE HISTORY

Installed in June 1979, the unit accommodated two of a family of five. For two months (August and February) all five persons used the unit full time. The family's diet included a lot of meat.

The unit was started with peat moss and water. The users added a cup of peat moss and stirred the contents after each use. The fan was used only when the unit was in use. The waste material was removed monthly and disposed of at a county septage disposal area by a licensed septic tank pumper.

### HIGHLIGHTS

During the two months that the unit was used by five people, major capacity problems occurred. After each overload, a septic tank pumper removed the contents, allowing a new start-up. Other efforts to control the problem included: addition of more peat moss; increased ventilation; and increased heat in bathroom. The users wrapped their vent pipe to prevent odor-causing leaks and also added a half cup of baking soda to combat odors. The owners suspected an undersized vent stack (4" when 6" was recommended) was the causing inadequate ventilation which hindered prompt reduction of the waste pile.

The unit overflowed once into the pasteurization chamber and once over the top hole. The fan clogged when peat moss was drawn from the chamber into the next fan.

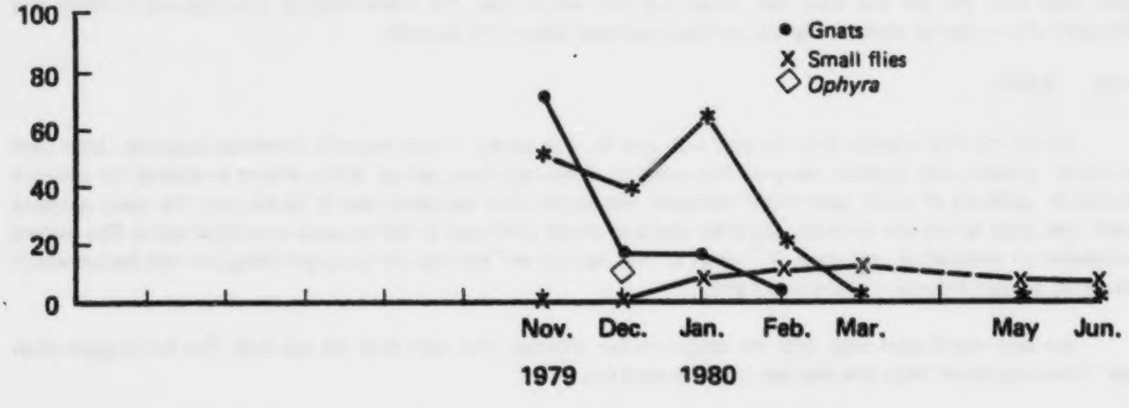
Mite swabs of the toilet seat were taken monthly from September 19, 1979 through June 1980. Of these 10 swabs, only the January sample was positive with 12 mites counted.

TABLE 1 UNIT U: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| September 1979 | M | $4.3 \times 10^3$ | $8.0 \times 10^2$ | | | | |
| October 1979 | M | $3.3 \times 10^5$ | $5.0 \times 10^3$ | | | | |
| November 1979 | M | $7.9 \times 10^5$ | $1.1 \times 10^5$ | Proteus mirabilis<br>Citrobacter freundii | Appearance: Fresh feces. No parasites seen. No known human pathogens found. | None Isolated | |
| January 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | >6 hours "pasteurized" |
| May 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 6 hours "pasteurized" |
| June 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 6 hours "pasteurized" |

TABLE 2 UNIT U: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| September 1979 | M | 7.8 | 78 | 23 | 79 | 21 |
| October 1979 | M | 7.3 | 75 | 25 | 75 | 25 |
| November 1979 | M | 8.3 | 71 | 29 | 67 | 33 |
| January 1980 | C | 8.2 | 78 | 22 | 79 | 21 |
| May 1980 | C | 8.3 | 84 | 16 | 70 | 30 |
| June 1980 | C | 7.9 | 83 | 18 | 75 | 25 |
| Finished (C) | | | | | | |
| Geometric Mean | | 8.0 | 82 | 19 | 75 | 25 |
| Range | | 7.9 – 8.3 | 78 – 84 | 16 – 22 | 70 – 79 | 21 – 30 |
| N = | | 3 | 3 | 3 | 3 | 3 |



GRAPH 1 OCCURRENCE OF FLYING INSECTS

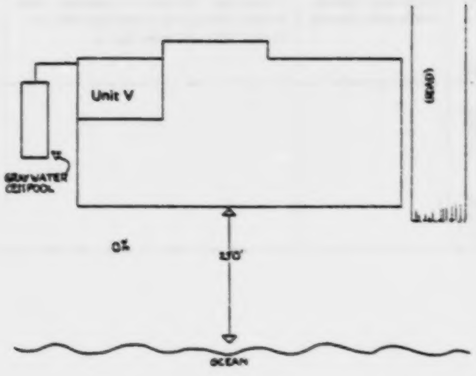
## UNIT V

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 6–8 feet |
| Soil Percolation: | < 1 min./in. |
| Depth to Bedrock: | > 4 feet |
| Slope: | 0 percent |
| Lot Size: | .11 acre |
| Other: | • Located in upstairs bathroom<br>• Sandy soil, 200–250 feet to ocean |

### UNIT DESIGN

| | |
|---|---|
| Type: | Box-like humus toilet with rotor, Bioloo |
| Ventilation: | • 4" PVC pipe to the ceiling and a 6" pipe above the roof line<br>• The 6" pipe was surrounded and insulated with an 8" galvanized pipe<br>• 8" turbine on top |
| Other: | • Heater and fan<br>• Vent pipe is not screened<br>• Toilet seat does not have seal |



### SERVICE HISTORY

The unit was installed in April 1979, and in the study from August 1979. One person, a tenant, used the unit with occasional guests. The user's diet included some meat.

Peat moss was used to start the pile and was subsequently added with each use. The tenant occasionally added kitchen waste to the unit and kept the toilet seat closed when not in use. When the pile dried out, the user would spray the pile lightly with water to allow easy turning. The fan was used daily. The pile was mixed daily with the rotor and the "finished" contents were removed monthly with an unmarked small shovel and disposed of by putting the wastes in a plastic bag which was then placed into the user's garbage can.

### HIGHLIGHTS

According to the tenant, the pasteurizing chamber worked well. Insects and odors were problems which were noted by the project observer.

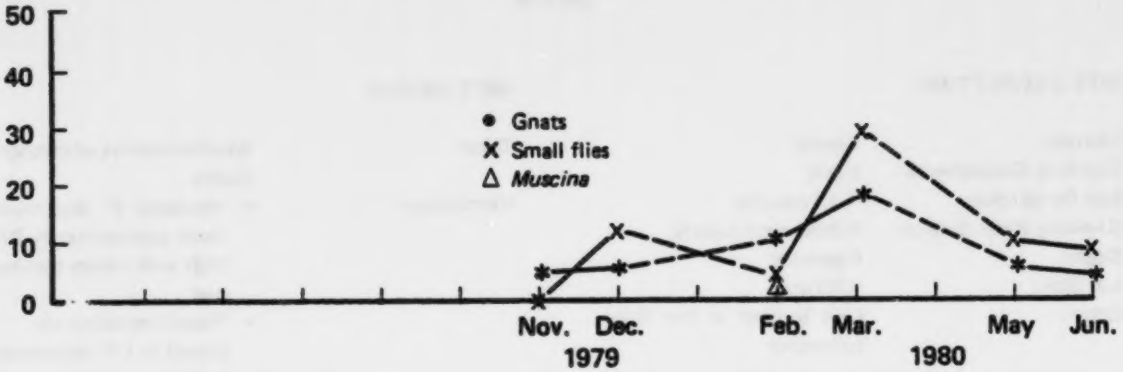
During one week in March, six people used the unit resulting in liquid overflow from the storage chamber to the pasteurizing chamber through the air intake. The owner also broke one of the wing nuts that held the service door in place.

## TABLE 1 UNIT V: MICROBIOLOGICAL DATA

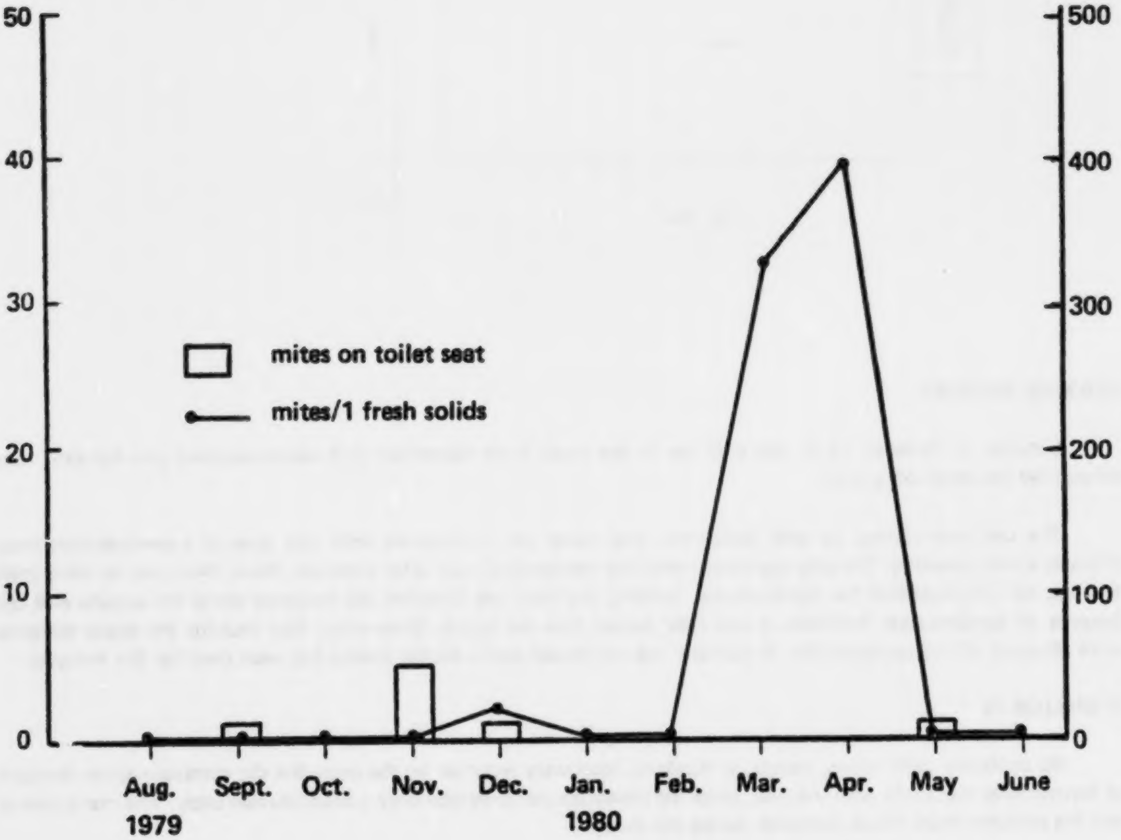
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | M | $2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | |
| September 1979 | M | $2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | |
| October 1979 | M | $2.2 \times 10^6$ | $2.2 \times 10^6$ | | | | |
| November 1979 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 4 hour pasteurized |
| May 1980 | C | $3.3 \times 10^3$ | $3.3 \times 10^3$ | | Six-hour "Pasteurized" Compost–Appearance: Wet compost. Occasional non-viable larvae, probably free-living. No known human parasites found. | | 6 hour pasteurized |
| June 1980 | C | $3.3 \times 10^4$ | $7.9 \times 10^3$ | Citrobacter freundii<br>Unidentified isolates | "Pasteurized" Compost–Appearance: Wet muddy compost. No parasites found. No known human parasites found. | | 5.5 hour pasteurized |
| June 1980 | X | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | Peat moss |
| Mixed (M) | | | | | | | |
| Geometric Mean | | $4.4 \times 10^3$ | $<4.4 \times 10^3$ | | | | |
| Range | | $10^2 - 10^6$ | $10^2 - 10^6$ | | | | |
| N = | | 3 | 3 | | | | |
| Finished (C) | | | | | | | |
| Geometric Mean | | $2.8 \times 10^3$ | $1.7 \times 10^3$ | | | | |
| Range | | $>10^2 - 10^4$ | $>10^2 - 10^3$ | | | | |
| N = | | 3 | 3 | | | | |

## TABLE 2 UNIT V: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | M | 8.4 | 79 | 21 | 69 | 31 |
| September 1979 | M | 8.5 | 78 | 22 | 67 | 33 |
| October 1979 | M | 8.0 | 79 | 21 | 69 | 31 |
| November 1979 | C | 8.6 | 81 | 19 | 62 | 38 |
| May 1980 | C | 7.8 | 85 | 15 | 64 | 36 |
| June 1980 | C | 7.4 | 83 | 17 | 80 | 20 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.9 | 83 | 17 | 68 | 30 |
| Range | | 7.8 – 8.6 | 81 – 85 | 15 – 19 | 62 – 80 | 20 – 38 |
| N = | | 3 | 3 | 3 | 3 | 3 |



GRAPH 1  OCCURRENCE OF FLYING INSECTS



GRAPH 2  OCCURRENCE OF MITES

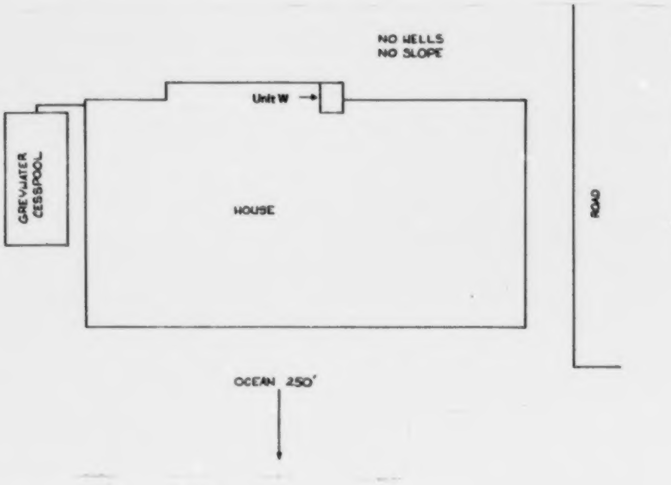
## UNIT W

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 8 feet |
| Soil Percolation: | < 45 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 0 percent |
| Lot Size: | 1/10 acre |
| Other: | Unit located in first floor bathroom |

### UNIT DESIGN

| | |
|---|---|
| Type: | Box-like humus with rotor, Bioloo |
| Ventilation: | • Insulated 6" aluminum stack approximately 20' high with rotary turbine cap<br>• Foam insulation enclosed in 10" galvanized steel<br>• Electrical fan in vent |



### SERVICE HISTORY

Installed in October 1979, the unit was in the study from November and accommodated one full-time user whose diet included some meat.

The unit was started up with peat moss and water and maintained with two cups of a sawdust/peat moss mixture added monthly. The pile was mixed with the mechanical rotor after each use. When there was no wind draft the user ran the electrical fan continuously. Initially the vent was installed and insulated along the outside wall but because of condensation problems it was later moved into the house. Once every four months the waste contents were disposed of in a compost pile. A specially marked shovel and a double plastic bag were used for this removal.

### HIGHLIGHTS

No problems with odors, insects, or liquid buildup were reported by the user. She did complain about the lack of instructions that came with the unit, since the manufacturer provided only a Scandinavian copy. The metal screws and the compost vault doors corroded during the study.

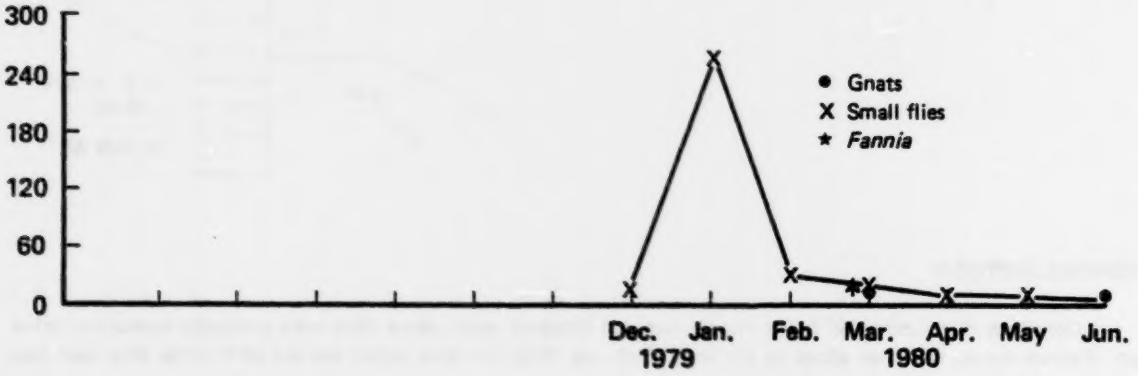
Mite swabs of the toilet seat were taken monthly from November 1979 through June 1980. One swab was positive for two mites.

### TABLE 1 UNIT W: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| February 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | Pasteurized and stored one month. |
| April 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 12 hours pasteurized |
| May 1980 | C | $2.4 \times 10^4$ | $3.3 \times 10^4$ | | | | 6 hours pasteurized |
| June 1980 | C | $<2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 6 hours pasteurized |

### TABLE 2 UNIT W: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| February 1980 | C | 7.7 | 80 | 20 | 70 | 30 |
| April 1980 | C | 7.4 | 78 | 22 | 69 | 31 |
| April 1980 | C | 7.7 | 80 | 20 | 61 | 39 |
| June 1980 | C | 8.1 | 79 | 21 | 67 | 33 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.7 | 79 | 21 | 67 | 33 |
| Range | | 7.4 – 8.1 | 78 – 80 | 20 – 22 | 61 – 70 | 30 – 39 |
| N = | | 4 | 4 | 4 | 4 | 4 |



GRAPH 1 OCCURRENCE OF FLYING INSECTS

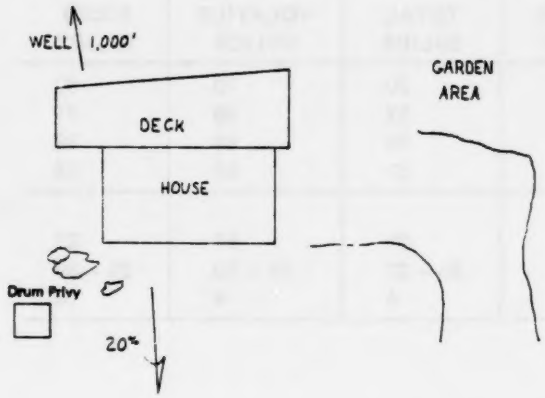
## UNIT AA

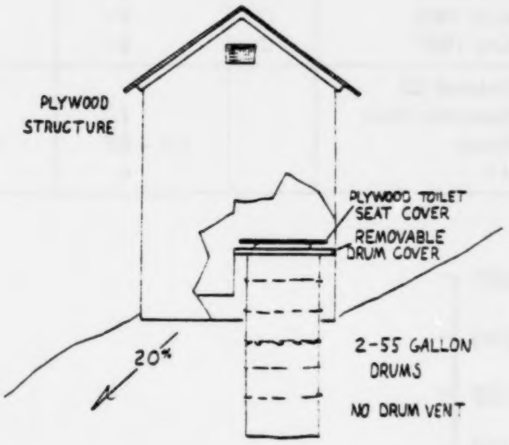
### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Soil Percolation: | 5 min./in. |
| Drinking Water Source: | Subsurface spring 1000 feet from house |
| Slope: | 20 percent |
| Lot Size: | 40 acres |
| Other: | • Unit located 30 feet down slope from house<br>• North facing slope |

### UNIT DESIGN

| | |
|---|---|
| Type: | Drum privy |
| Size: | 110 gallon; two 55 gallon in series. |
| Construction Material: | • Inner tube seal between barrels and structure<br>• Plywood top structure |
| Ventilation: | • None on first pair<br>• 2" PVC pipe vent on second pair |
| Insulation: | None |
| Other: | Unique variation of the 55-gallon drum unit; two drums combined and buried like a vault privy with a mobile structure on top. |


WELL 1,000'
DECK
HOUSE
GARDEN AREA
Drum Privy
20%


PLYWOOD STRUCTURE
PLYWOOD TOILET SEAT COVER
REMOVABLE DRUM COVER
20%
2-55 GALLON DRUMS
NO DRUM VENT

### SERVICE HISTORY

Constructed in Spring 1977, the system had two full-time users whose diets were primarily vegetarian. Urine and kitchen wastes were not added to the unit. Until July 1979, the users added one cup of fir chips after each use; after July, chopped straw was used.

When the barrels filled, the structure was moved to the other barrel arrangement. For the study period, the owner moved the structure twice. The first set of barrels was buried in place and the second set was destroyed in a forest fire and subsequently covered over.

## HIGHLIGHTS

Both barrel arrangements flooded and were three-quarter filled with groundwater or rainwater intrusion. The bottoms of both of the barrels rusted and leaked. Neither set of drums contained any type of interior protective coating.

The low fly counts on the July 1979 tape resulted from a drum change in June and reduced tape exposure time. However, the sanitarian reported high counts of adult muscid flies in the drum at the time of the July visit.

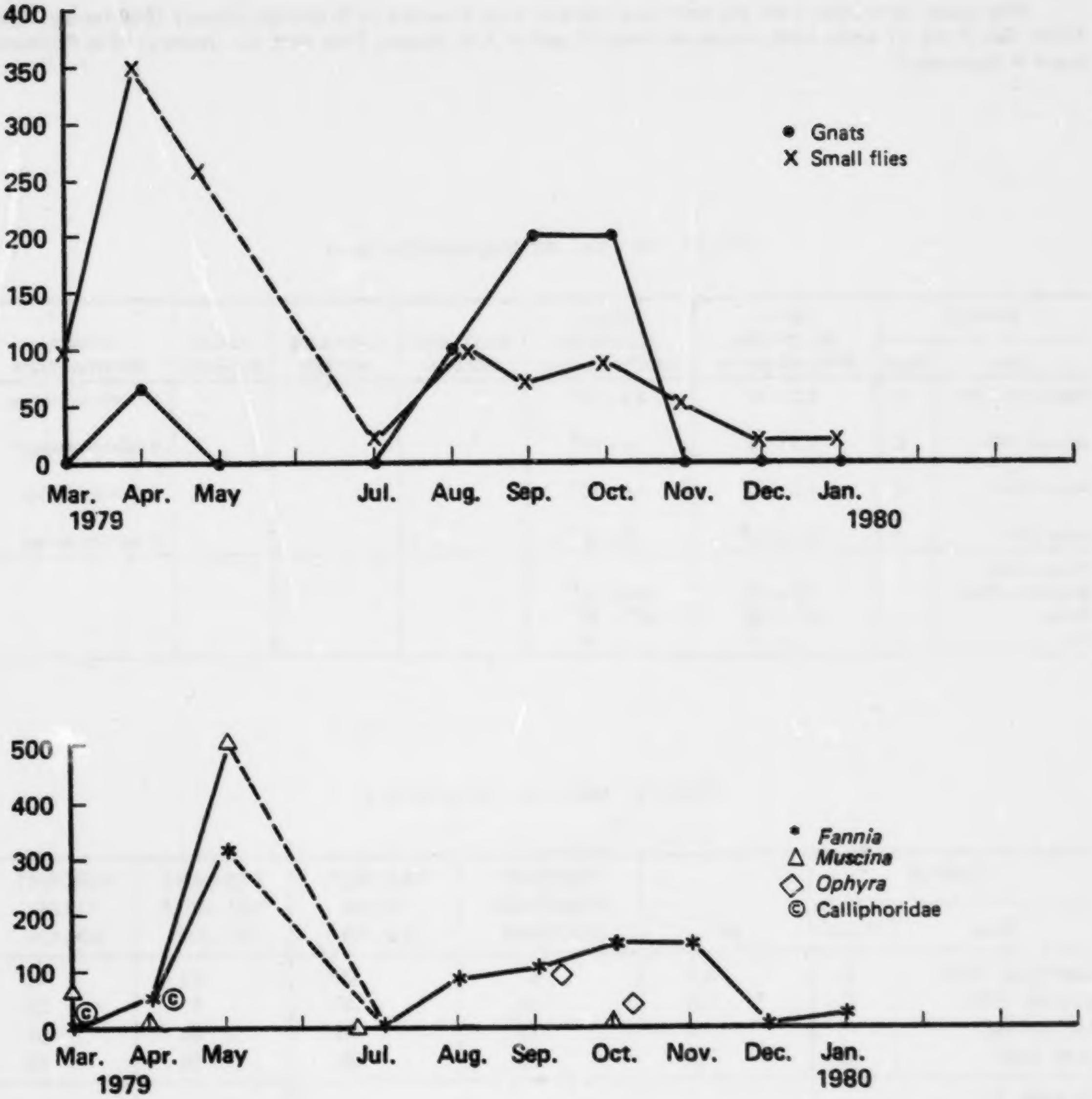
Mite swabs were taken from the toilet seat monthly from February 1979 through January 1980 (except April 1979). Six of the 11 swabs were positive for mites (1 each in July, August, December, and January; 10 in February; and 4 in November).

### TABLE 1 UNIT AA: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| September 1979 | C | $2.3 \times 10^6$ | $2.3 \times 10^6$ | | | | <1 month storage |
| January 1980 | C | $1.3 \times 10^9$ | $1.4 \times 10^6$ | | | | 5 months storage |
| March 1980 | C | $9.2 \times 10^9$ | $1.4 \times 10^8$ | | | | 7 months storage |
| June 1980 | C | $2.3 \times 10^8$ | $1.7 \times 10^7$ | | | | 3 months storage |
| Finished (C) | | | | | | | |
| Geometric Mean | | $2.8 \times 10^8$ | $9.4 \times 10^6$ | | | | |
| Range | | $10^6 - 10^9$ | $10^6 - 10^8$ | | | | |
| N = | | 4 | 4 | | | | |

### TABLE 2 UNIT AA: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| September 1979 | C | 8.4 | 51 | 49 | 52 | 48 |
| January 1980 | C | 7.8 | 64 | 36 | 61 | 39 |
| March 1980 | C | 7.4 | 75 | 25 | 68 | 32 |
| June 1980 | C | 7.9 | 68 | 32 | 55 | 45 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.9 | 64 | 34 | 59 | 41 |
| Range | | 7.4 – 8.4 | 51 – 75 | 32 – 49 | 52 – 68 | 32 – 48 |
| N = | | 4 | 4 | 4 | 4 | 4 |

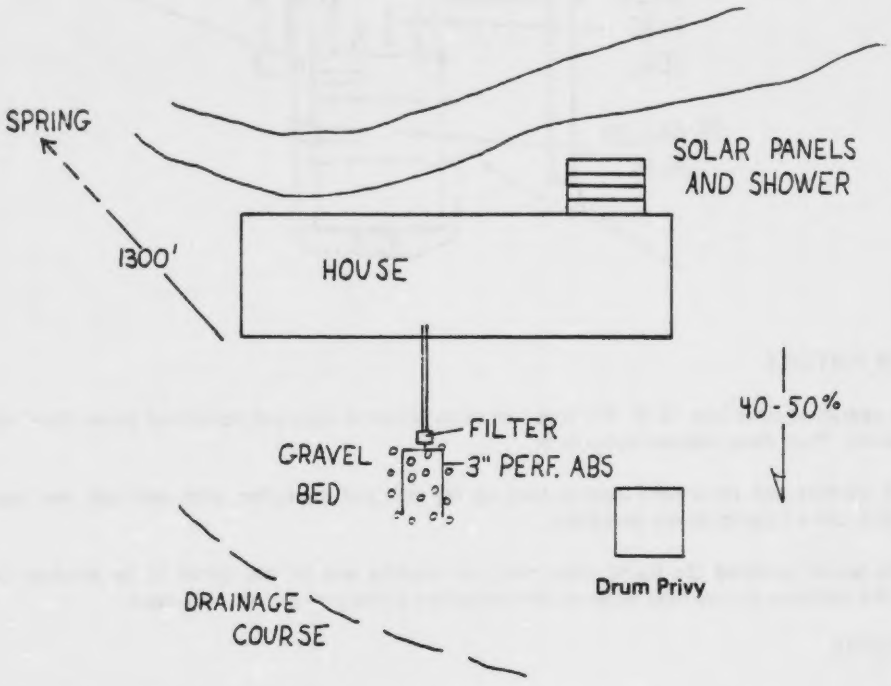


GRAPH 1 OCCURRENCE OF FLYING INSECTS

## UNIT BB

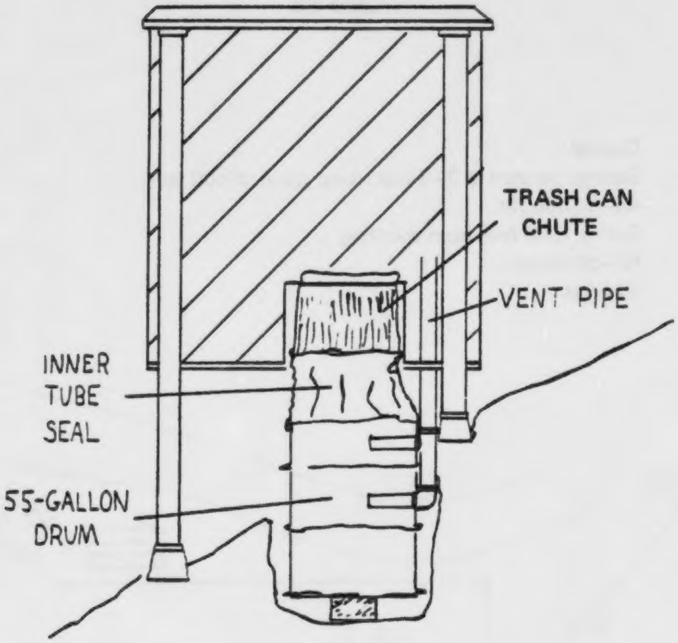
### SITE DESCRIPTION

**Climate:** Coastal
**Depth to Groundwater:** Springs perched @ 2–5 feet; deep water @ 400 feet
**Soil Percolation:** 45–60 min./in.
**Drinking Water Source:** Spring 1300 feet from dwelling
**Slope:** 40–50 percent
**Lot Size:** 40 acres


SPRING
1300'
HOUSE
SOLAR PANELS AND SHOWER
FILTER
GRAVEL BED
3" PERF. ABS
40-50%
Drum Privy
DRAINAGE COURSE

### UNIT DESIGN

**Type:** Drum privy
**Size:** 55 gallon drum
**Ventilation:** 2" ABS pipe from inside drum to above roof
**Other:**
- Inner tube seal between drum and trash can toilet chute
- Toilet seat seal
- Screened vent pipe
- Gaps around door of outhouse



## SERVICE HISTORY

In operation since late 1976, this unit had three full-time users and occasional guests (four visitors two—three days/month). Their diets included some meat.

Fir sawdust and ashes were used to start up the unit and thereafter, with each use, two cups of fir sawdust were added. Urine separation was practiced.

The owner replaced the barrel once every six months and let the barrel sit for another six months before burying the contents around fruit trees on site; unmarked gloves and shovels were used.

## HIGHLIGHTS

The owner reported the rubber inner tube seal as being very difficult to replace during drum changes. The inner tube seal leaked near the top seam of the barrel. The owner switched from sawdust to ash in November 1979 because the sawdust was not decomposing.

Odors and insects were reported as controllable with an abundance of "household" flies in the summer. Sticky tapes and pest strips were used as controls.

Fly tapes were difficult to hang in this unit and 7 of the 12 tapes were lost in the vault. Fly counts for the five recovered tapes are tabulated below.

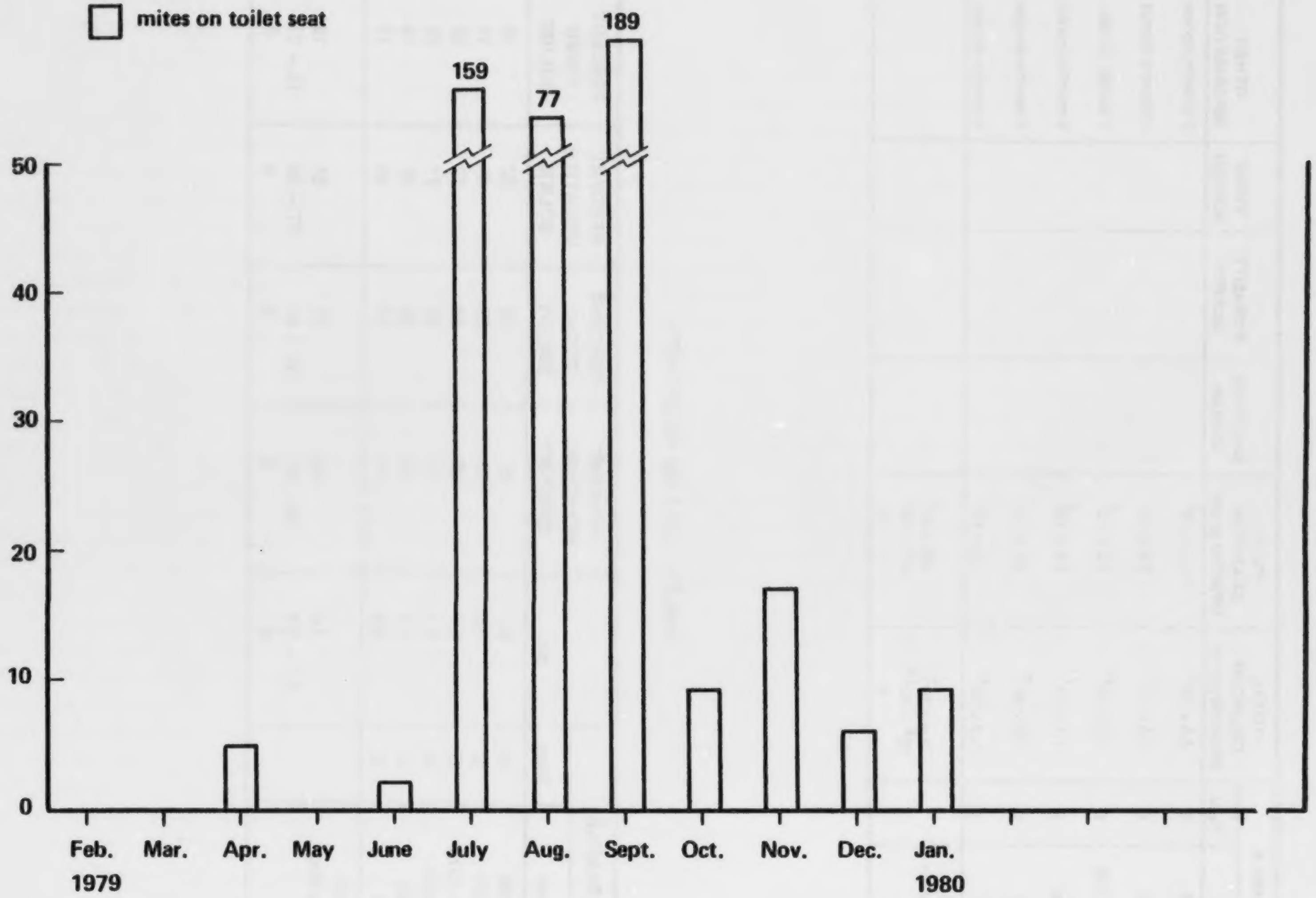
| | MARCH | APRIL | JUNE | AUGUST | DECEMBER |
|---|---|---|---|---|---|
| Gnats | 2 | 70 | 0 | 200 | 0 |
| Small flies | 50 | 160 | 1,100 | 0 | 0 |
| *Fannia* | 100 | 75 | 500 | 4 | 35 |
| *Muscina* | 10 | 50 | 0 | 0 | 0 |

### TABLE 1 UNIT BB: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $3.3 \times 10^8$ | $<2.0 \times 10^2$ | | | | 6 months storage |
| August 1979 | C | $2.3 \times 10^8$ | $7.9 \times 10^7$ | | | | 0 months storage |
| November 1979 | C | $1.6 \times 10^{10}$ | $3.5 \times 10^9$ | | | | 1 month storage |
| January 1980 | C | $1.1 \times 10^9$ | $7.0 \times 10^8$ | | | | 3 months storage |
| March 1980 | C | $7.9 \times 10^7$ | $2.3 \times 10^7$ | | | | 5 months storage |
| June 1980 | C | $1.7 \times 10^6$ | $1.3 \times 10^5$ | | | | 8 months storage |
| Finished (C) | | | | | | | |
| Geometric Mean | | $2.4 \times 10^8$ | $3.6 \times 10^7$ | | | | |
| Range | | $10^6 - 10^{10}$ | $10^5 - 10^9$ | | | | |
| N = | | 6 | 5 | | | | |

### TABLE 2 UNIT BB: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 6.7 | 81 | 19 | 82 | 18 |
| August 1979 | C | 7.6 | 71 | 29 | 81 | 19 |
| November 1979 | C | 8.7 | 36 | 64 | 77 | 23 |
| January 1980 | C | 7.7 | 73 | 27 | 77 | 23 |
| March 1980 | C | 7.1 | 70 | 30 | 85 | 15 |
| June 1980 | C | 6.9 | 70 | 30 | 83 | 17 |
| Finished (C) | | | | | | |
| Geometric Mean | | 7.4 | 65 | 31 | 81 | 19 |
| Range | | 6.7 – 8.7 | 36 – 81 | 27 – 64 | 77 – 85 | 15 – 23 |
| N = | | 6 | 6 | 6 | 6 | 6 |



GRAPH 1 UNIT BB: OCCURRENCE OF MITES

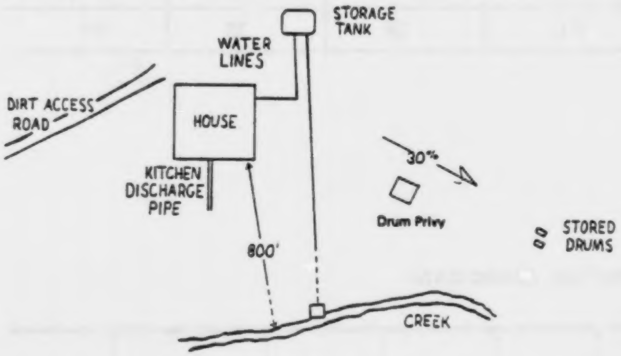
## UNIT CC

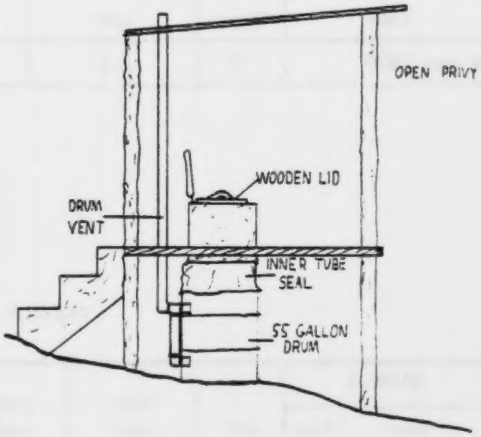
### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 400 feet |
| Soil Percolation: | 45–60 min./in. |
| Drinking Water Source: | Creek (800 feet below house) to storage tank |
| Slope: | 30 percent |
| Lot Size: | 50 acres |
| Other: | Unit located 50 feet north of house |

### UNIT DESIGN

| | |
|---|---|
| Type: | 55-gallon drum |
| Construction Material: | Inner tube seal between drum and platform; (stretched over top of drum; sealed to base with nails and caulking) |
| Ventilation: | 2" PVC vent through drum to above roof |
| Other: | • Unit is open platform structure on supporting poles with roof and no walls<br>• Screened vent pipe<br>• Wooden toilet lid, sealed with foam insulation, held in place with rocks |


STORAGE TANK
WATER LINES
DIRT ACCESS ROAD
HOUSE
KITCHEN DISCHARGE PIPE
30%
Drum Privy
800'
STORED DRUMS
CREEK


OPEN PRIVY
WOODEN LID
DRUM VENT
INNER TUBE SEAL
55 GALLON DRUM

### SERVICE HISTORY

Started up in January 1977, this unit had two part-time users (equivalent to one full-time user) with very few visitors. The owners' diets included some meat.

The unit was started up with fir sawdust and maintained by adding one cup of sawdust after each use. The drum was replaced approximately every 1½ years and stored vented until odorless, then the contents were buried several hundred yards away from the unit. Unmarked gloves and shovels were used.

### HIGHLIGHTS

The owners reported a problem with rainfall infiltration through the vent pipe and also some problems with the inner tube seal around the base. Summer heat had cracked the rubber. The owners used a silicone sealer to correct leaks in the drum.

Odors were reported as a problem on hot days or when the drum filled above the top vent in the barrel. Sticky tapes were used next to the privy in an attempt to control insects.

## TABLE 1 UNIT CC: MICROBIOLOGICAL DATA

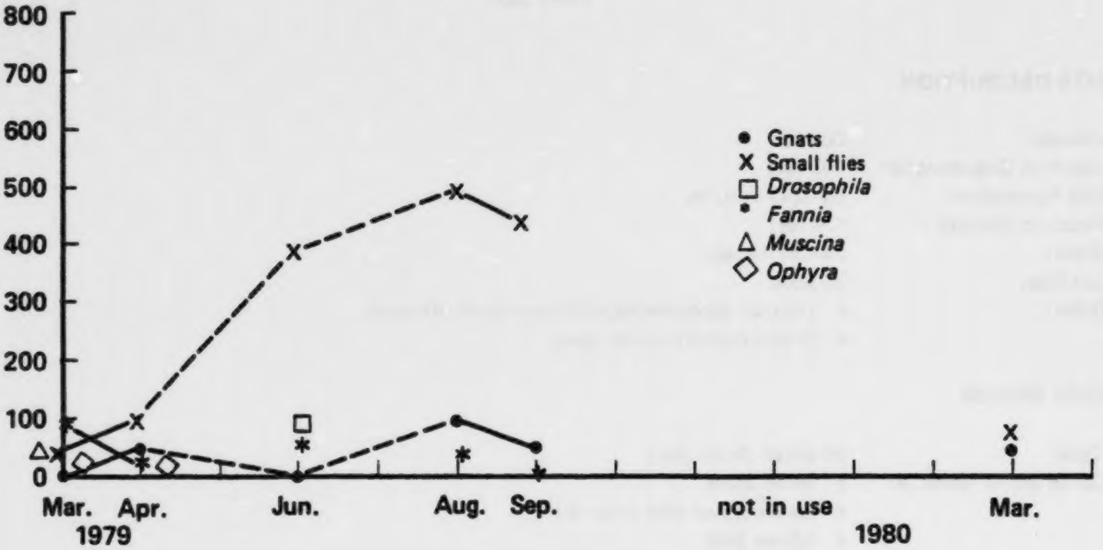
| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $2.0 \times 10^2$ | $<2.0 \times 10^2$ | | | | 12 months storage |
| August 1979 | L | $2.3 \times 10^2$ | $<2.0 \times 10$ | | | | |

## TABLE 2 UNIT CC: SOLID DATA

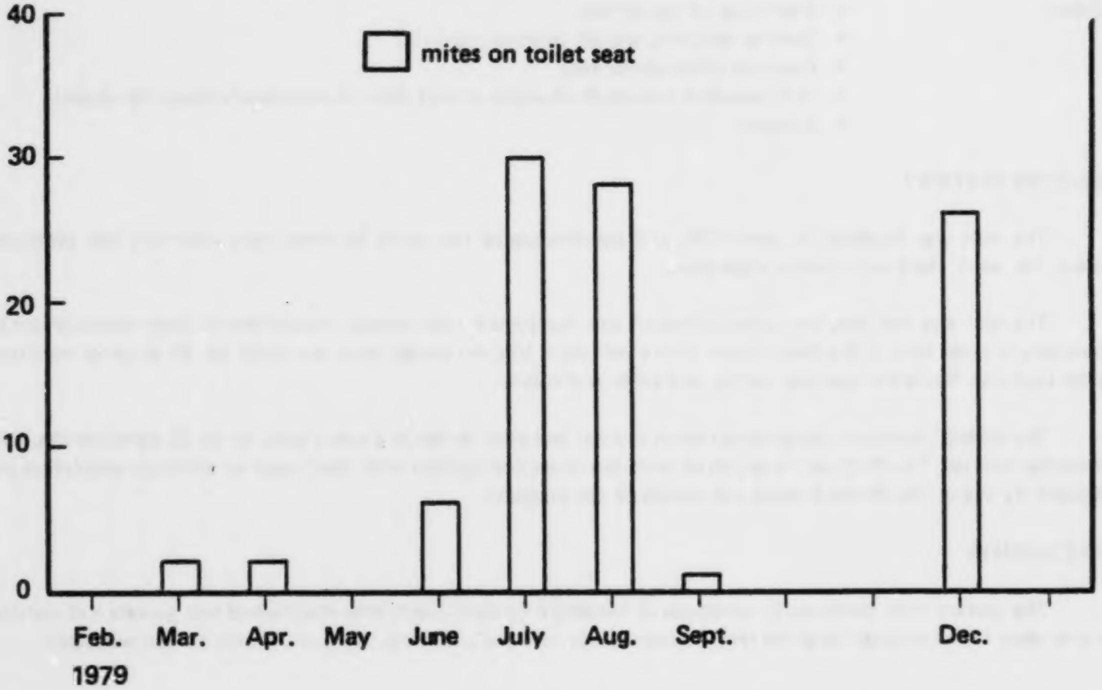
| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 8.9 | 71 | 29 | 33 | 67 |

## TABLE 3 UNIT CC: LIQUID DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC $\mu$mhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| August 1979 | L | 8.9 | $5.0 \times 10^3$ | $2.3 \times 10^4$ | $4.8 \times 10^4$ | $1.8 \times 10^4$ | $1.8 \times 10^3$ | – | 97.5 | $3.8 \times 10^4$ |



GRAPH 1 UNIT CC: OCCURRENCE OF FLYING INSECTS



GRAPH 2 UNIT CC: OCCURRENCE OF MITES

## UNIT DD

### SITE DESCRIPTION

Climate: Coastal
Depth to Groundwater: 400 feet
Soil Percolation: 60–240 min./in.
Depth to Bedrock: < 4 feet
Slope: 25–30 percent
Lot Size: 36 acres
Other:
- Located approximately 50 feet south of house
- Drums stored in sunny spot

### UNIT DESIGN

Type: 55-gallon drum privy
Construction Material:
- Metal drum
- Caulking seal with drum lid
- Scissor jack
- Plastic (bottomless) garbage can
- Wood enclosure (4′ x 7′)

Ventilation:
- Capped, perforated PVC pipe extending through hole in drum's side to 4" vent pipe whch runs up side of enclosure
- House also vented

Other:
- Storm cap on top of vent
- Weather stripping around toilet seat and lid
- Foam on underside of seat
- Hole punched at bottom of elbow in vent pipe (to eliminate leakage into drum)
- 3 drums

### SERVICE HISTORY

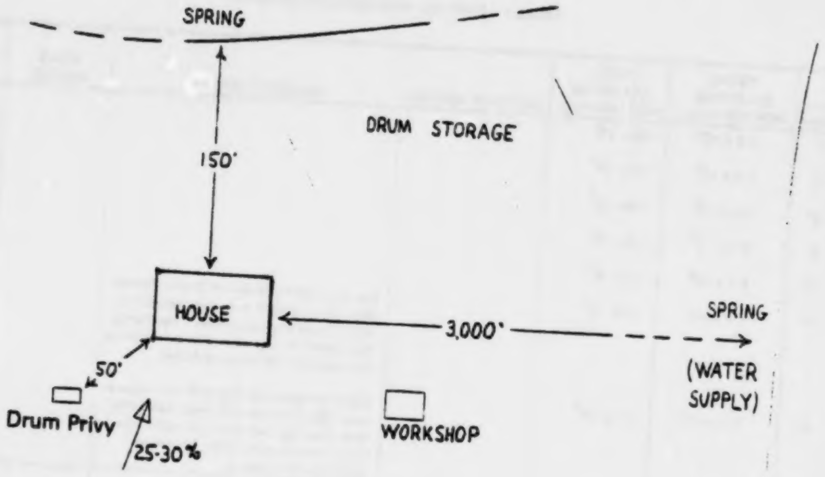
The unit was installed in June 1978, and accommodated two adult full-time users with very few additional users. The users' diets were mainly vegetarian.

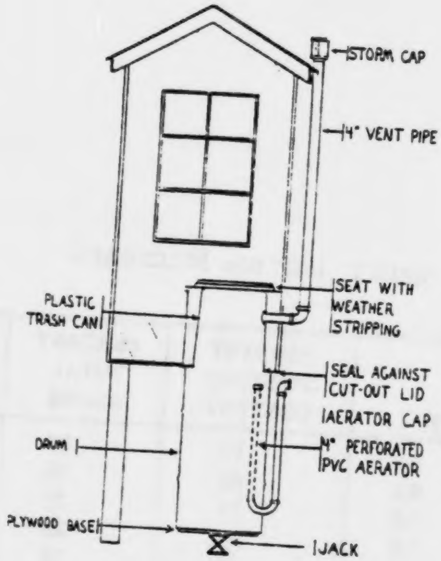
The unit was not used for urine collection and the owners took special precautions to keep rainwater out by punching a small hole in the lower elbow of the vent pipe. Kitchen wastes were not added but fir shavings were used after each use. The toilet seat was kept closed when not in use.

The drums filled up in about six to seven months and were stored in a sunny spot for six to eight months, with monthly rollings. The PVC vent was stored with the drum and stuffed with steel wool to allow air circulation and prevent fly entry. The finished waste was buried on the property.

### HIGHLIGHTS

The owners were particularly conscious of keeping a fly-tight room; they maintained seat gaskets and installed a seat cover which snapped over the seat. The sanitarian reported anaerobic odors at the unit on two occasions.


SPRING
150'
DRUM STORAGE
HOUSE
3,000'
SPRING
(WATER SUPPLY)
50'
Drum Privy
25-30%
WORKSHOP


STORM CAP
4" VENT PIPE
SEAT WITH WEATHER STRIPPING
PLASTIC TRASH CAN
SEAL AGAINST CUT-OUT LID
AERATOR CAP
DRUM
4" PERFORATED PVC AERATOR
PLYWOOD BASE
JACK

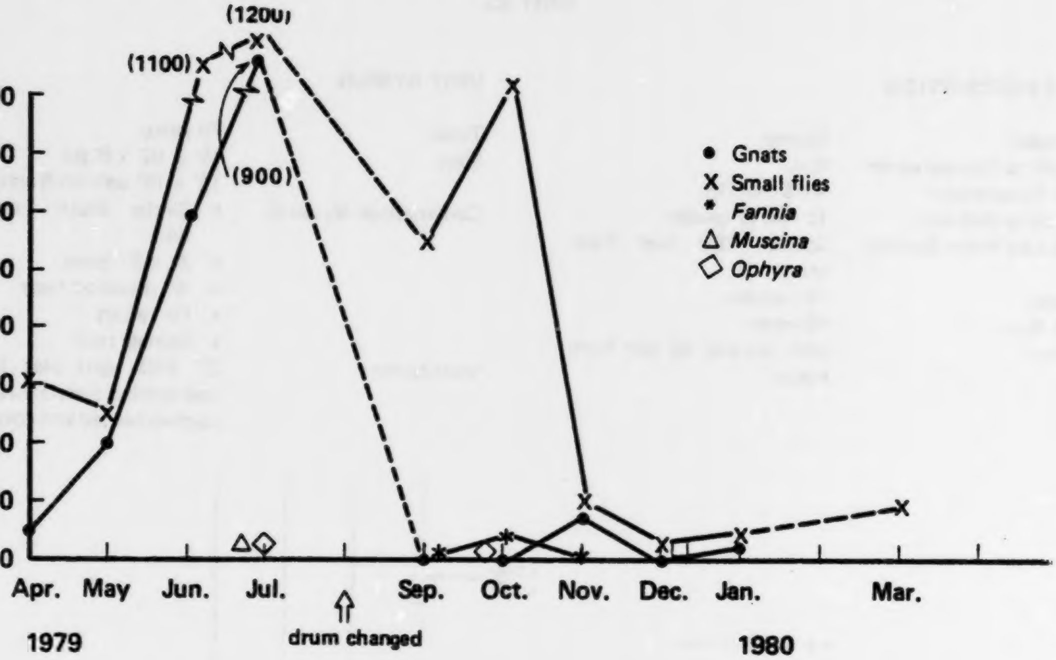
### TABLE 1 UNIT DD: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 mg/ml | FECAL COLIFORM MPN/100 mg/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | C | $4.3 \times 10^4$ | $8.0 \times 10^2$ | | | | 12 months |
| September 1979 | C | $5.4 \times 10^9$ | $4.9 \times 10^7$ | | | | 1 month |
| January 1980 | C* | $3.5 \times 10^9$ | $4.9 \times 10^7$ | | | | 1 month |
| March 1980 | C | $7.0 \times 10^5$ | $7.9 \times 10^4$ | | | | 6 months |
| March 1980 | C* | $1.7 \times 10^8$ | $2.2 \times 10^7$ | | | | 3 months |
| June 1980 | C* | $7.9 \times 10^7$ | $1.3 \times 10^7$ | | Stored compost. 55-Gallon Drum—Appearance: Wet compost with intact appearing feces. Occasional egg, probably free-living. Many cyst-like objects, probably free-living. No known human parasites found. | | 9 months |
| June 1980 | C | $1.6 \times 10^{10}$ | $1.7 \times 10^7$ | | Stored compost. 55-Gallon Drum—Appearance: Wet compost with intact appearing feces. Few eggs and larvae, probably free-living. Occasional mite egg. No known human parasites found. | | |
| Finished (C)<br>Geometric Mean<br>Range<br>N = | | <br>$7.4 \times 10^7$<br>$10^4 - 10^{10}$<br>7 | <br>$2.6 \times 10^6$<br>$10^2 - 10^7$<br>7 | | | | |

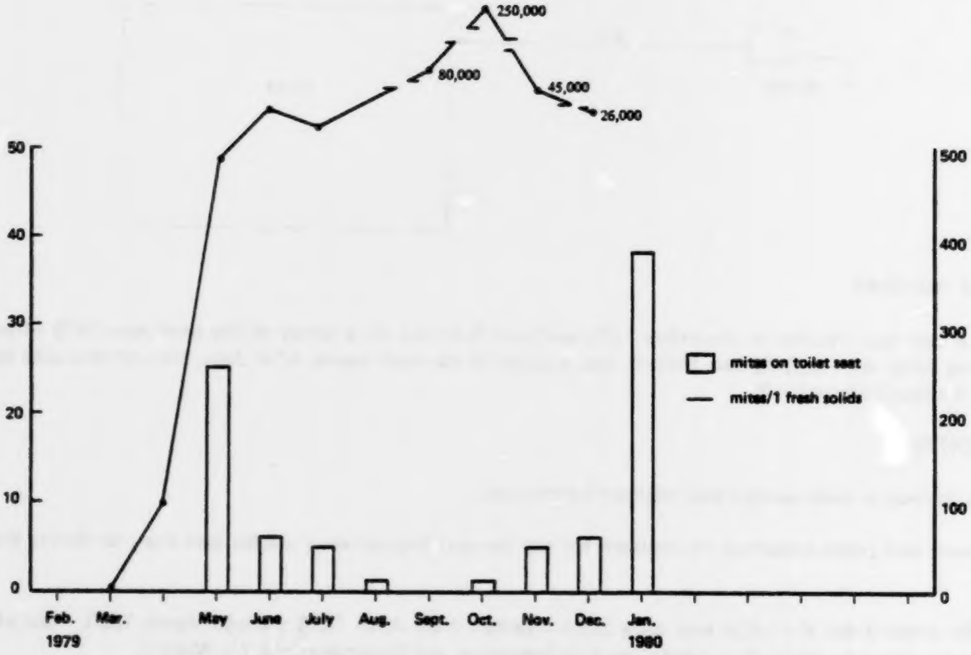
* Same drum.

### TABLE 2 UNIT DD: SOLID DATA

| SAMPLE | | pH | PERCENT MOISTURE CONTENT | PERCENT TOTAL SOLIDS | PERCENT VOLATILE SOLIDS | PERCENT FIXED SOLIDS |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | C | 7.2 | 72 | 28 | 72 | 28 |
| September 1979 | C | 8.0 | 65 | 35 | 93 | 7 |
| January 1980 | C | 7.6 | 74 | 27 | 77 | 23 |
| March 1980 | C | 7.5 | 71 | 29 | 76 | 24 |
| March 1980 | C | 7.2 | 70 | 30 | 80 | 20 |
| Finished (C) | | | | | | |
| Geometric Mean | – | 7.5 | 70 | 30 | 79 | 18 |
| Range | – | 7.2 – 8.0 | 65 – 72 | 27 – 35 | 72 – 93 | 7 – 28 |
| N = | – | 5 | 5 | 5 | 5 | 5 |



GRAPH 1 UNIT DD: OCCURRENCE OF FLYING INSECTS



GRAPH 2 UNIT DD: OCCURRENCE OF MITES

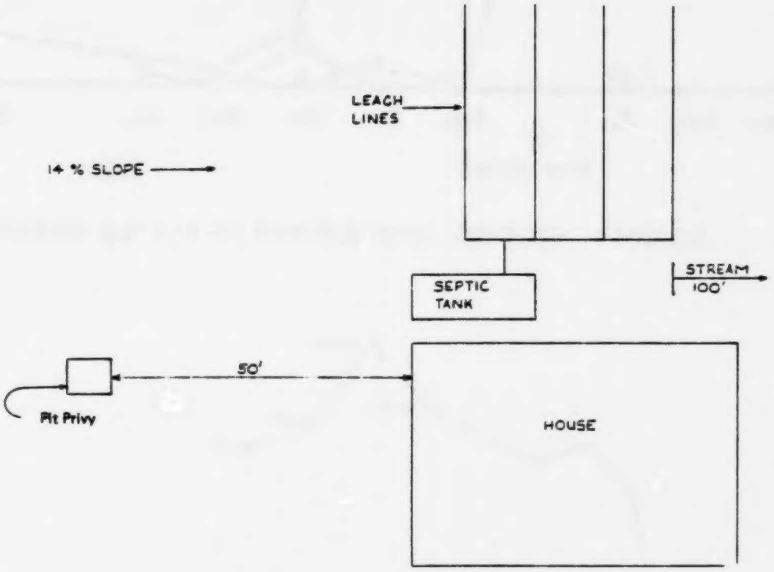
## UNIT EE

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | N.A. |
| Soil Percolation: | <45 min./in. |
| Depth to Bedrock: | 10 feet or greater |
| Drinking Water Source: | Stream 200 feet from privy |
| Slope: | 14 percent |
| Lot Size: | 40 acres |
| Other: | Unit located 50 feet from house |

### UNIT DESIGN

| | |
|---|---|
| Type: | Pit privy |
| Size: | 10′ x 10′ x 8′ pit<br>12′ x 12′ unit (A-frame) |
| Construction Material: | • Cinder block foundation<br>• 2″ x 6″ joists<br>• ¾″ plywood floor<br>• Fir rafters<br>• Shingle roof |
| Ventilation: | 2″ ABS vent pipe from wall behind throne through roof—screened and covered |



### SERVICE HISTORY

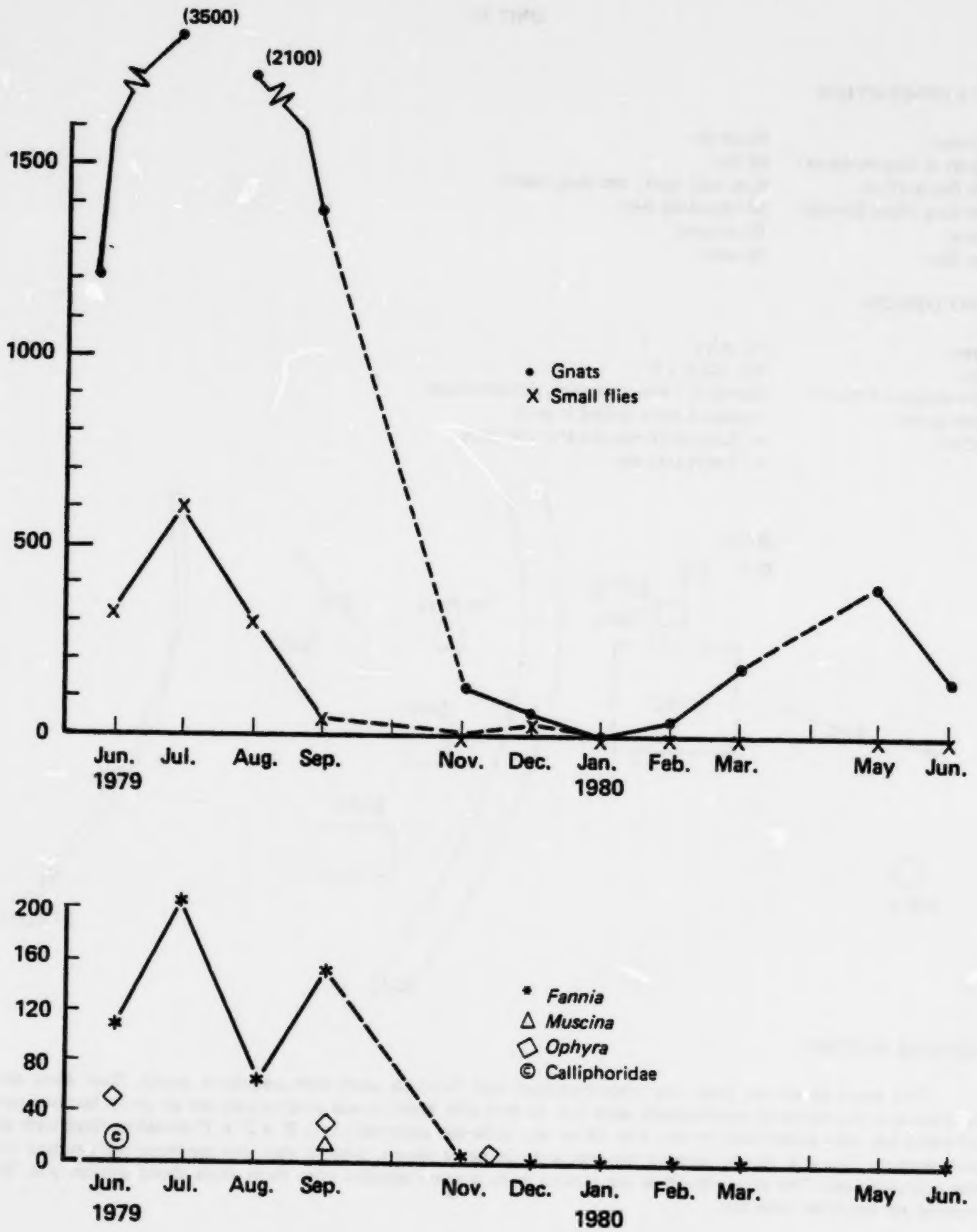
This unit was installed in December 1978 and used full time by a family of five until June 1979 when a box-like humus toilet with topping bar, Unit R, was installed in the main house. After June, the unit was used by guests or when the electricity was off.

### HIGHLIGHTS

No start-up or maintenance was required for this unit.

Insects and odors presented no problem for the owners. Groundwater seeped into the unit during the winter months.

Mite swabs from the toilet seat were taken monthly from April 1979 through March 1980. Four of the 12 swabs were positive for mites (2 in April; 1 each in September and November; and 7 in March).



GRAPH 1 UNIT EE: OCCURRENCE OF FLYING INSECTS

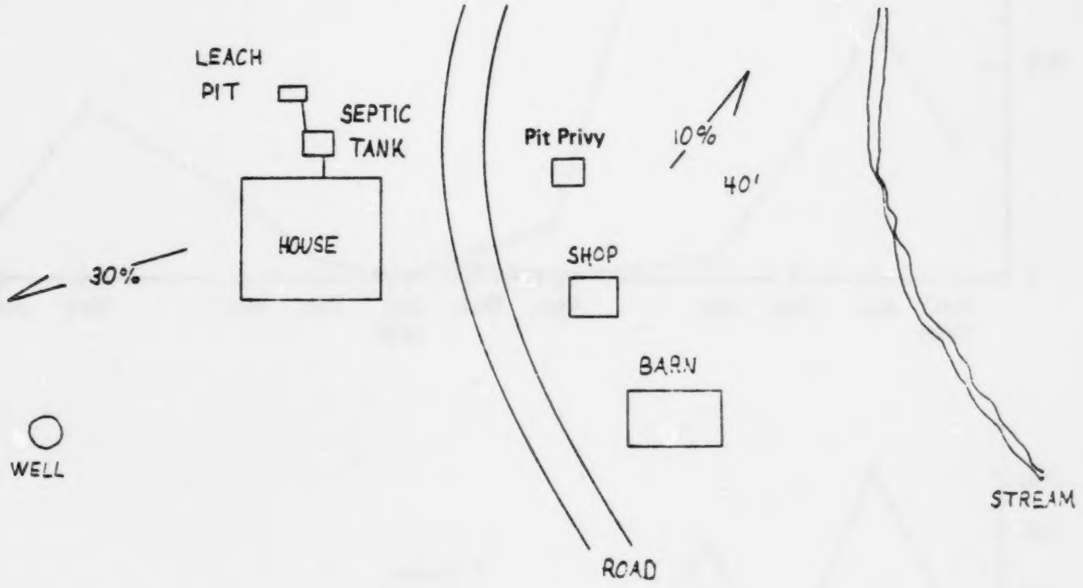
## UNIT FF

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Mountain |
| Depth to Groundwater: | 40 feet |
| Soil Percolation: | N.A. (soil type: red clay, loam) |
| Drinking Water Source: | 25-foot deep well |
| Slope: | 10 percent |
| Lot Size: | 35 acres |

### UNIT DESIGN

| | |
|---|---|
| Type: | Pit privy |
| Size: | 3½′ x 3½′ x 6′ |
| Construction Material: | Standard frame structure, concrete base |
| Ventilation: | Screened holes drilled in peak |
| Other: | • Screened structure and vent pipe<br>• Toilet seat seal |

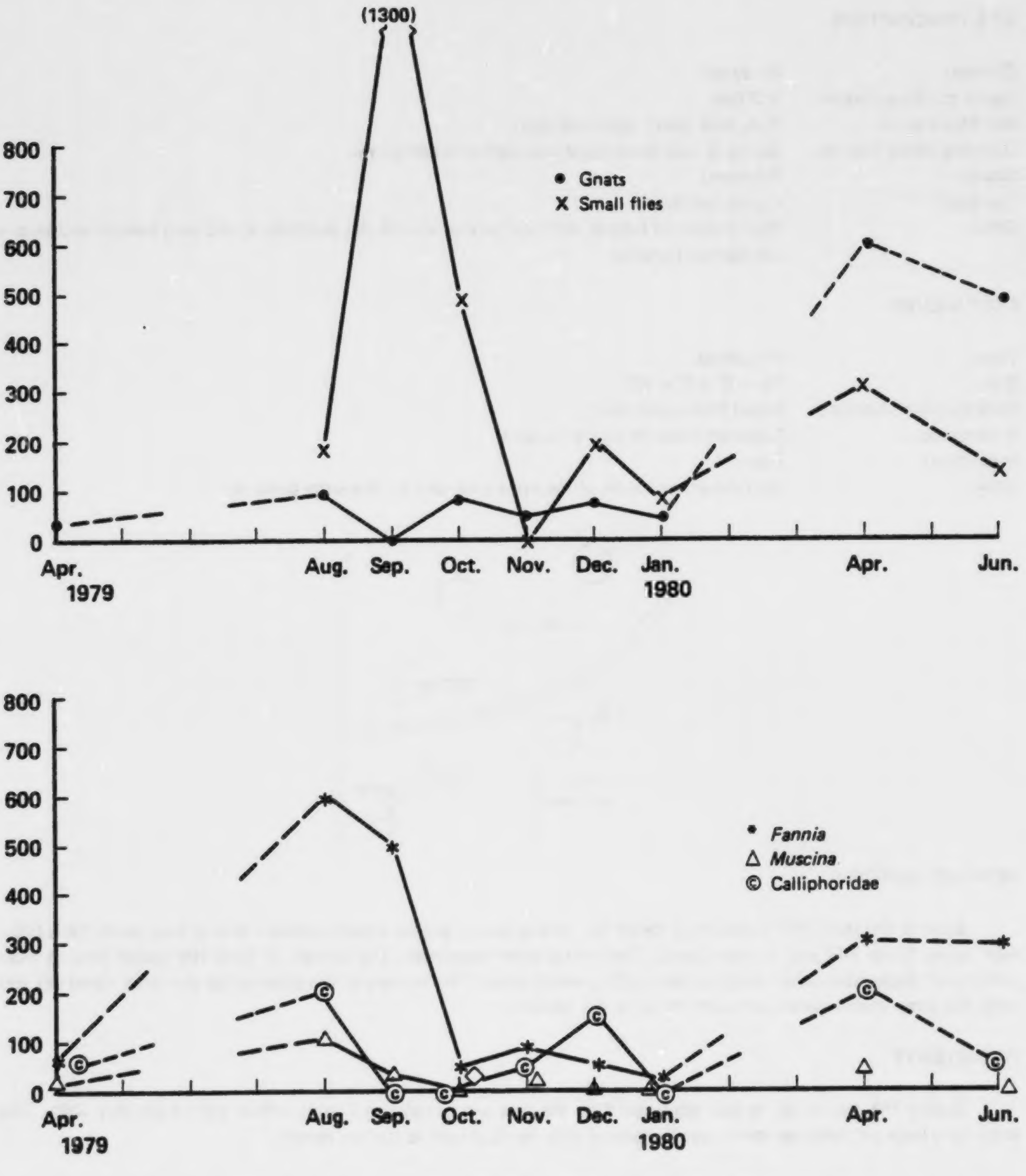


### SERVICE HISTORY

This two-year-old pit privy has accommodated four full-time users with occasional guests. Their diets were omnivorous. Maintenance requirements were low for this unit. Nothing was used to start the pit privy, but two cups of wood ash were added daily to the pile. Urine was collected separately in a 2′ x 2′ x 2′ container filled with ash and sawdust. This was located outside the unit and was never stirred. After a year, the container was emptied into the compost heap. The privy structure was moved to its present location after three years above another site. The vacated pit was filled with dirt.

The owners attempted to control insect problems with fly bait.

No mites were found on ten toilet seat swabs of this unit from March 1979 through June 1980.



GRAPH 1 UNIT FF: OCCURRENCE OF FLYING INSECTS

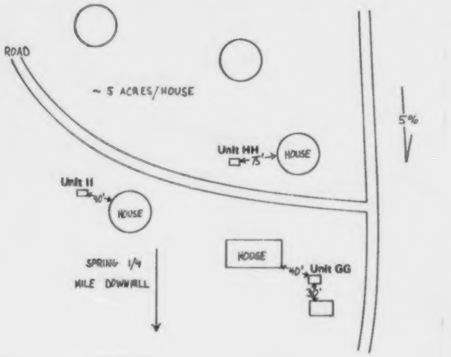
## UNITS GG, HH, AND II

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Mountain |
| Depth to Groundwater: | > 3 feet |
| Soil Percolation: | N.A. (soil type: tight red clay) |
| Drinking Water Source: | Spring ¼ mile downslope pumped to holding tank |
| Slope: | 5 percent |
| Lot Size: | 5 acres per house |
| Other: | This cluster of houses with pit privies shared site conditions and unit designs and thus is considered together. |

### UNIT DESIGN

| | |
|---|---|
| Type: | Pit privies |
| Size: | Pit – 5′ x 5′ x 10′ |
| Construction Material: | Wood frame and floor |
| Ventilation: | Screened holes in superstructure |
| Insulation: | None |
| Other: | All privies were built at the same time and by the same persons. |



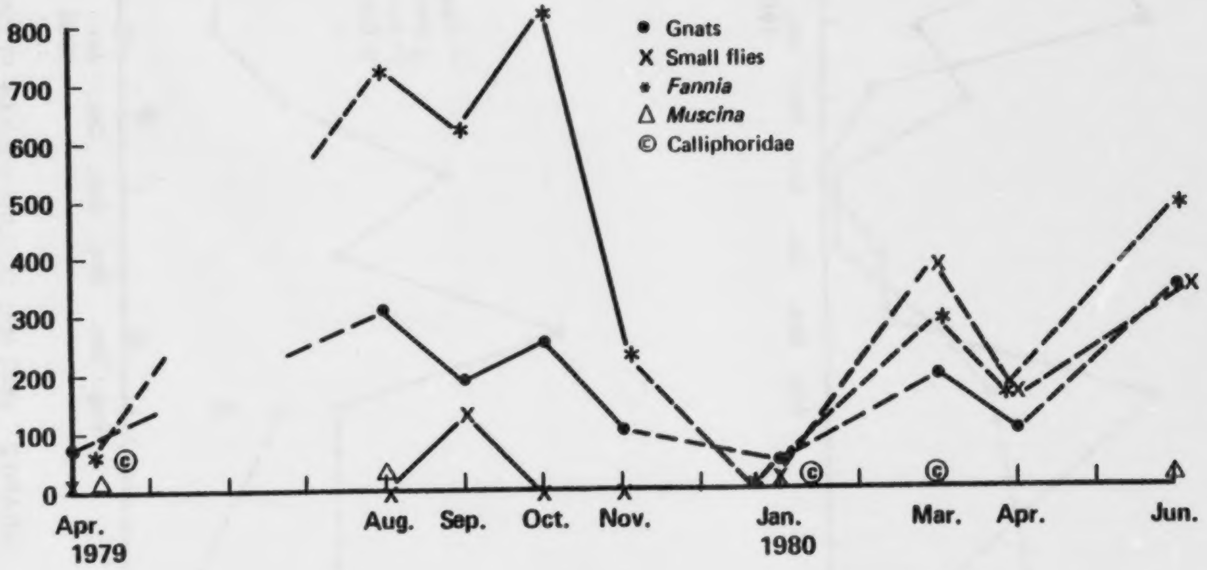
### SERVICE HISTORY

Built in October 1977 following a forest fire, this group of privies accommodated two to four users (Unit GG—four users; Units HH and II—two users). Their diets were vegetarian. The owners of Unit HH added lime to their privy until September when they started adding wood ashes. The owners of the other units also used wood ash and lime. No other maintenance was performed by the owners.

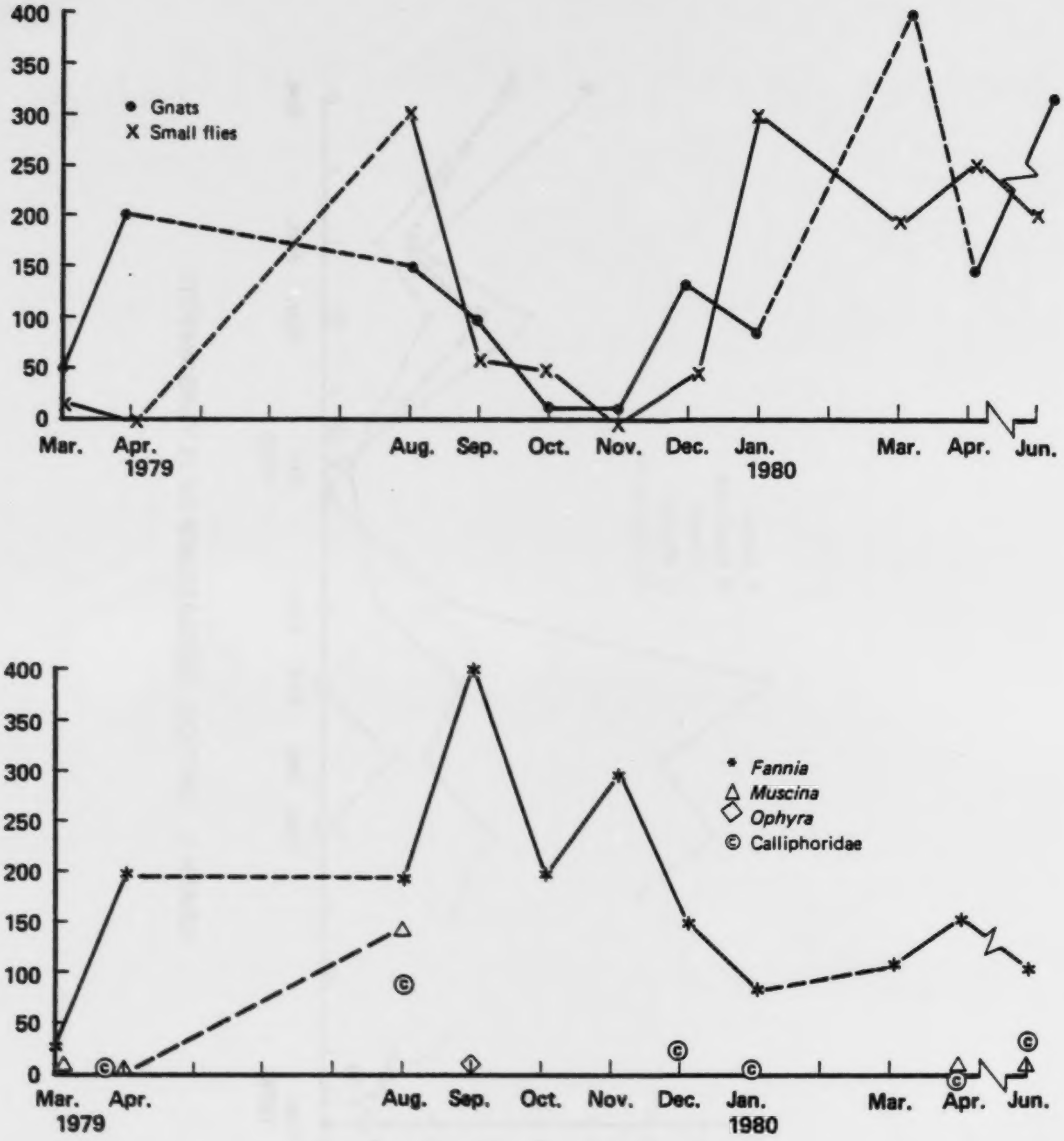
### HIGHLIGHTS

During the site visits, it was observed that the pits were retaining liquids within their tight clay walls. The extremely large pit volumes easily accommodated this liquid as well as surface runoff.

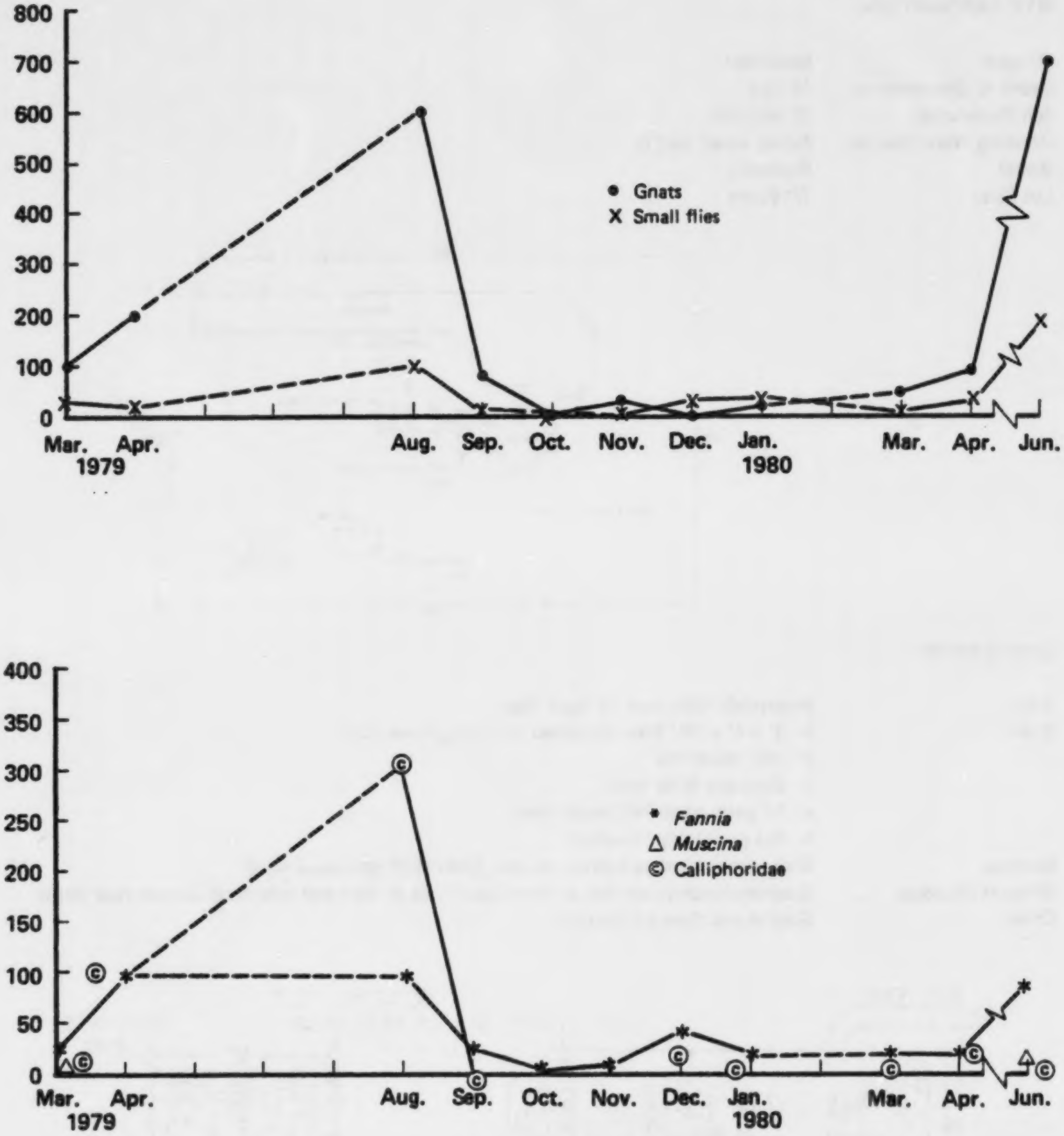
Very few mites were found on the toilet seat swabs from these units. Unit GG had one mite in November from seven swabs; Unit HH had three out of eight swabs positive (two in September and one each in November 1979 and March 1980); Unit II had four out of five swabs positive (four in February and one each in September and November 1979, and two in April 1980).



GRAPH 1 UNIT GG: OCCURRENCE OF FLYING INSECTS



GRAPH 2 UNIT HH: OCCURRENCE OF FLYING INSECTS

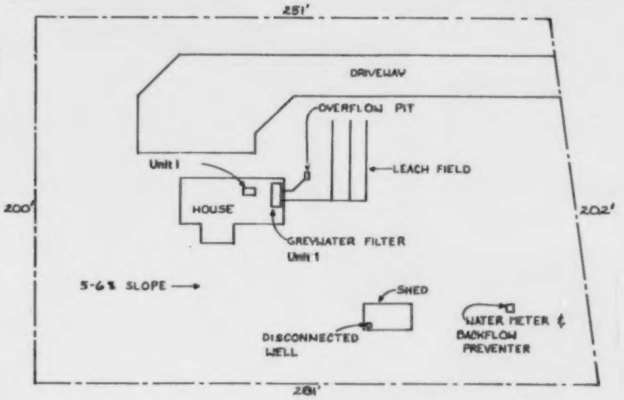


GRAPH 3 UNIT II: OCCURRENCE OF FLYING INSECTS

## UNIT 1

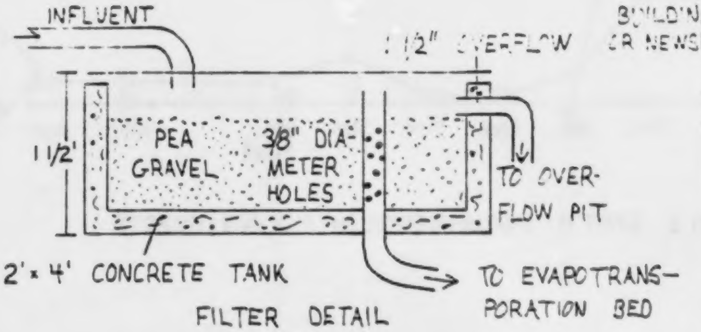
### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Mountain |
| Depth to Groundwater: | 10 feet |
| Soil Percolation: | 21 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 6 percent |
| Lot Size: | 7/10 acre |

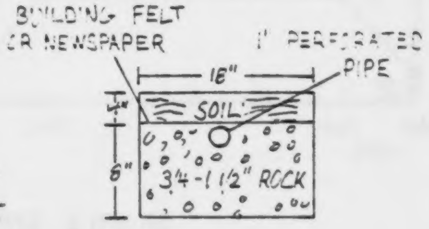

251'
DRIVEWAY
OVERFLOW PIT
Unit I
LEACH FIELD
200'
HOUSE
202'
GREYWATER FILTER
Unit 1
5-6% SLOPE
SHED
WATER METER &
BACKFLOW
PREVENTER
DISCONNECTED
WELL
281'

### UNIT DESIGN

| | |
|---|---|
| Type: | Anaerobic filter tank to leach field |
| Size: | • 2' x 4' x 1½' filter (designed for 250 gallons/day)<br>• 155' leach line<br>• Concrete filter tank<br>• 1" perforated PVC leach lines<br>• Pea gravel filter medium |
| Sources: | Dishwasher, clothes washer, shower, sinks (225 gpd maximum) |
| Effluent Disposal: | Evapotransportation bed; shallow leach lines to fruit and pine trees located near house |
| Other: | Special overflow pit for tank |


INFLUENT
1 1/2" OVERFLOW
1 1/2'
PEA
GRAVEL
3/8" DIAMETER
HOLES
TO OVERFLOW PIT
2' x 4' CONCRETE TANK
TO EVAPOTRANSPORATION BED

FILTER DETAIL


BUILDING FELT
OR NEWSPAPER
1" PERFORATED
PIPE
18"
4"
SOIL
6"
3/4-1 1/2" ROCK

TRENCH DETAIL

## SERVICE HISTORY

Installed in fall 1976, this system served two regular users who were pleased with its performance. They flushed the system with a hose once a year and collected "undesirable" liquids (Epsom salts, bath oils, products containing chlorine or boron) in a separate container, dumping them in the middle of the driveway.

## HIGHLIGHTS

The design of the anaerobic filter did not allow sufficient retention time for anaerobic stabilization of wastewater pollutants. The drain location caused a short circuiting of the filter media by the wastewater. Insects were observed and collected from the tank.

### TABLE 1 UNIT 1: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| September 1979 | E | – | – | | | | Sampling error |
| October 1979 | E | – | – | | | | Sampling error |
| January 1980 | E | $4.9 \times 10^7$ | $4.9 \times 10^7$ | | | | |

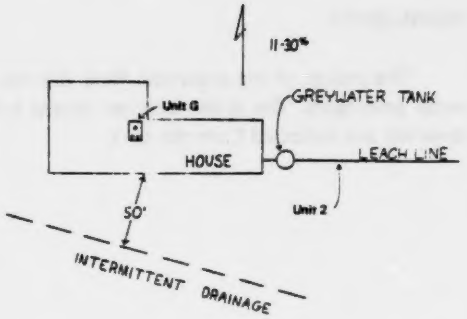
### TABLE 2 UNIT 1: ANALYTICAL DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
| September 1979 | E | 7.1 | 1,700 | 5,400 | 290 | 9,800 | 280 | – | 0.2 | 200 |
| October 1979 | E | 6.0 | 300 | 620 | 160 | 590 | 20 | – | 1.4 | 180 |
| January 1980 | E | 6.4 | 2,000 | 5,100 | 230 | 3,500 | 130 | – | 0.2 | 290 |

## UNIT 2

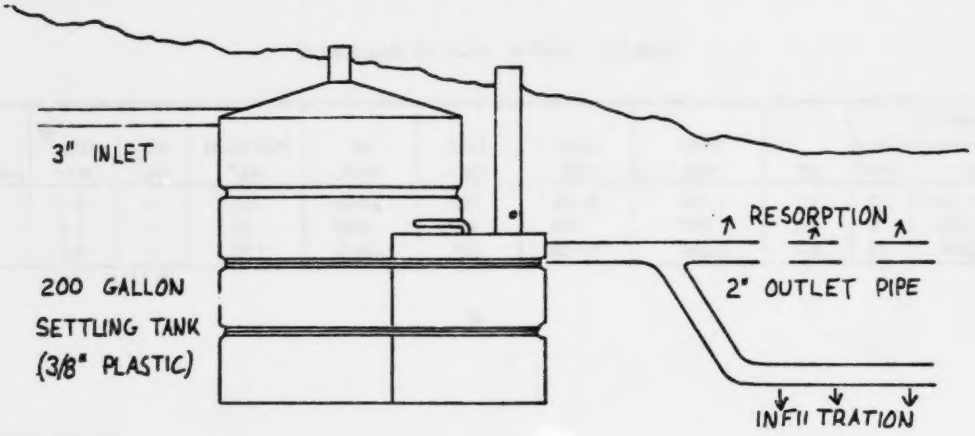
### SITE DESCRIPTION

| | |
|---|---|
| **Climate:** | **Mountain** |
| **Depth to Groundwater:** | **> 20 feet** |
| **Soil Percolation:** | **45–60 min./in.** |
| **Drinking Water Source:** | **Public water supply** |
| **Slope:** | **11–30 percent** |
| **Lot Size:** | **5 acres** |
| **Other:** | **Settling tanks located 12 feet from house** |


11-30%
Unit G
GREYWATER TANK
HOUSE
LEACH LINE
50'
Unit 2
INTERMITTENT DRAINAGE

### UNIT DESIGN

| | |
|---|---|
| **Type:** | **Commercial settling tanks and leach line** |
| **Size:** | **• One 200-gallon settling tank**<br>**• 50' x 18" x 2' leach line trench**<br>**• 3" plastic inlet pipe**<br>**• 2" plastic outlet pipe** |
| **Construction Material:** | **• Standard leach line rock**<br>**• 3/8" plastic settling tank**<br>**• Plastic pipe for inlet and outlet**<br>**• No filter material in tanks** |
| **Sources:** | **Bathroom and kitchen sinks, bathtub, shower, washing machine, and dishwasher (approximately 100 gpd)** |
| **Effluent Disposal:** | **Subsurface leach field to vegetable garden** |


3" INLET
RESORPTION
2" OUTLET PIPE
200 GALLON SETTLING TANK (3/8" PLASTIC)
INFILTRATION

### SERVICE HISTORY

**This commercial unit was installed in October 1979 and accommodated five full-time users. No maintenance was required and, after six months, no pump-out was necessary.**

### HIGHLIGHTS

**No problems with grease buildup, odors, or insects were reported.**

## TABLE 1 UNIT 2: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| November 1979 | I | $9.2 \times 10^8$ | $3.3 \times 10^7$ | | | |
| November 1979 | E | $9.2 \times 10^8$ | $1.3 \times 10^8$ | | | |
| December 1979 | I | $1.6 \times 10^9$ | $1.3 \times 10^8$ | | | |
| December 1979 | E | $1.6 \times 10^9$ | $7.9 \times 10^7$ | | | |
| January 1980 | I | $1.3 \times 10^8$ | $3.3 \times 10^6$ | | | |
| January 1980 | E | $\geqslant 2.4 \times 10^9$ | $3.3 \times 10^7$ | | | |
| February 1980 | I | $\geqslant 2.4 \times 10^9$ | $1.7 \times 10^7$ | | | |
| February 1980 | E | $\geqslant 2.4 \times 10^9$ | $7.9 \times 10^6$ | | | |
| March 1980 | I | $\geqslant 2.4 \times 10^9$ | $7.0 \times 10^5$ | | | |
| March 1980 | E | $1.6 \times 10^9$ | $7.9 \times 10^5$ | | | |
| April 1980 | I | $1.7 \times 10^8$ | $4.9 \times 10^5$ | Citrobacter freundii<br>Providencia rettgeri<br>Enterobacter cloacae<br>Klebsiella pneumoniae<br>Proteus vulgaris | | |
| April 1980 | E | $2.4 \times 10^8$ | $2.3 \times 10^5$ | Klebsiella pneumoniae<br>Enterobacter cloacae<br>Yersinia enterocolitica<br>Proteus vulgaris | | |
| May 1980 | I | $1.7 \times 10^7$ | $1.3 \times 10^6$ | | Effluent Grey Water—Appearance: Grey water. Few free-living ciliates. No known human parasites found. | |
| May 1980 | E | $1.7 \times 10^7$ | $1.3 \times 10^6$ | | | |
| June 1980 | I | $9.2 \times 10^8$ | $4.9 \times 10^6$ | | | |
| June 1980 | E | $\geqslant 9.4 \times 10^9$ | $7.0 \times 10^5$ | Klebsiella pneumoniae<br>Pseudomonas aeruginosa<br>Citrobacter freundii | Effluent Grey Water—Appearance: Grey water. Many ciliates. No known human parasites found. | None Isolated |
| **Influent (I)** | | | | | | |
| Geometric Mean | | $2.8 \times 10^8$ | $5.2 \times 10^6$ | | | |
| Range | | $10^7 - 10^9$ | $10^5 - 10^8$ | | | |
| N = | | 6 | 8 | | | |
| **Effluent (E)** | | | | | | |
| Geometric Mean | | $3.9 \times 10^8$ | $5.1 \times 10^6$ | | | |
| Range | | $10^7 - 10^9$ | $10^5 - 10^8$ | | | |
| N | | 5 | 8 | | | |

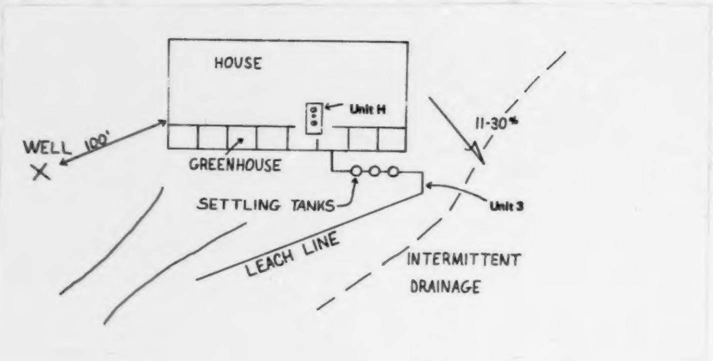
## TABLE 2 UNIT 2: LIQUID DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
| November 1979 | I | 6.1 | 330 | 430 | 300 | 70 | 10 | – | 1.8 | 280 |
| November 1979 | E | 6.2 | 560 | 860 | 320 | 280 | 20 | – | 3.2 | 300 |
| December 1979 | I | 5.8 | 230 | 380 | 290 | 70 | 30 | – | 1.8 | 310 |
| December 1979 | E | 6.2 | 270 | 570 | 300 | 140 | 20 | – | 1.7 | 310 |
| January 1980 | I | 6.8 | 90 | 50 | 170 | 270 | 10 | 0.1 | 1.3 | 170 |
| January 1980 | E | 6.7 | 320 | $1.1 \times 10^3$ | 190 | 350 | 30 | 0.3 | 2.9 | 60 |
| February 1980 | I | 6.3 | 110 | 330 | 350 | 80 | 10 | – | 1.8 | 290 |
| February 1980 | E | 6.0 | 380 | $1.2 \times 10^3$ | 300 | 520 | 20 | – | 2.7 | 270 |
| March 1980 | I | 6.4 | 120 | 100 | 230 | 30 | 20 | <0.1 | 0.2 | 270 |
| March 1980 | E | 6.4 | <130 | 50 | 200 | 330 | 20 | <0.1 | 1.5 | 280 |
| March 1980 | W | 6.7 | <1 | 3 | 60 | 10 | 1 | <0.1 | 1.0 | 50 |
| April 1980 | I | 5.7 | 230 | 240 | 240 | 70 | 10 | 0.1 | 0.3 | 210 |
| April 1980 | E | 5.9 | 400 | 610 | 300 | 220 | 20 | 0.1 | 3.1 | 270 |
| May 1980 | I | 6.1 | 120 | 210 | 150 | 60 | 10 | <0.1 | 0.7 | 130 |
| May 1980 | E | 6.3 | 190 | 460 | 190 | 250 | 10 | <0.1 | 0.9 | 170 |
| June 1980 | I | 6.2 | 100 | 200 | 140 | 20 | 20 | <0.1 | 0.8 | 240 |
| June 1980 | E | 6.1 | 220 | 470 | 190 | 120 | 20 | <0.1 | 1.2 | 280 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | | 6.2 | 150 | 200 | 220 | 60 | 14 | – | 0.8 | 230 |
| Range | | 5.7 – 6.8 | 90 – 330 | 50 – 430 | 140 – 350 | 20 – 270 | 10 – 30 | <0.1 – 0.1 | 0.2 – 1.8 | 130 – 310 |
| N = | | 8 | 8 | 8 | 8 | 8 | 8 | 5 | 8 | 8 |
| **Effluent (E)** | | | | | | | | | | |
| Geometric Mean | | 6.2 | 300 | 510 | 240 | 250 | 19 | – | 2.0 | 220 |
| Range | | 5.9 – 6.8 | 190 – 560 | 50 – $1.2 \times 10^3$ | 190 – 320 | 120 – 520 | 10 – 30 | <0.1 – 0.3 | 0.9 – 3.2 | 60 – 310 |
| N = | | 8 | 7 | 8 | 8 | 8 | 8 | 5 | 8 | 8 |

## UNIT 3

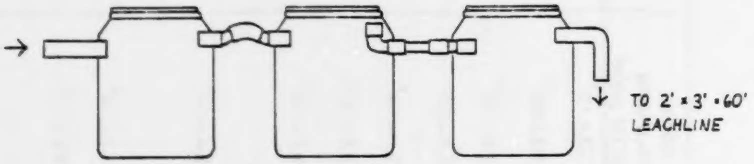
### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Mountain |
| Depth to Groundwater: | > 8 feet |
| Soil Percolation: | 45–60 min./in. |
| Drinking Water Source: | Well approximately 100 feet from house |
| Slope: | 11–30 percent |
| Lot Size: | 7 acres |


HOUSE
Unit H
11-30%
WELL 100'
GREENHOUSE
SETTLING TANKS
Unit 3
LEACH LINE
INTERMITTENT DRAINAGE

### UNIT DESIGN

| | |
|---|---|
| Type: | Commercial settling tanks and leach line |
| Size: | • 2' x 3' x 60' leach line<br>• Three 60-gallon settling tanks in series |
| Construction Material: | • Standard leach rock<br>• No filter material in tanks<br>• ¼" polybutylene settling tanks |
| Sources: | Bathroom, kitchen, dishwasher, laundry, shower and tub |
| Effluent Disposal: | Leach line |


TO 2' × 3' × 60' LEACHLINE

3 60 GALLON SETTLING TANKS
— 1/4" POLYBUTYLENE
— NO FILTER MATERIAL

### SERVICE HISTORY

Installed in November 1979, this system accommodated two full-time users. No maintenance was required.

### HIGHLIGHTS

The users reported effluent surfacing and odors which were both corrected by expanding the leach field. No problems with grease buildup or insects were reported

## TABLE 1 UNIT 3: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| January 1980 | I | $3.3 \times 10^{7}$ | $1.3 \times 10^{7}$ | | | |
| January 1980 | E | $3.3 \times 10^{7}$ | $4.9 \times 10^{7}$ | | | |
| February 1980 | I | $7.9 \times 10^{7}$ | $1.3 \times 10^{7}$ | | | |
| February 1980 | E | $1.3 \times 10^{8}$ | $1.3 \times 10^{7}$ | | | |
| March 1980 | I | $2.4 \times 10^{9}$ | $1.3 \times 10^{7}$ | | | |
| March 1980 | E | $2.4 \times 10^{9}$ | $3.3 \times 10^{6}$ | | | |
| April 1980 | I | $9.2 \times 10^{8}$ | $4.6 \times 10^{5}$ | | Influent Grey Water—Appearance: Grey water. No parasites found. No known human parasites found. | |
| April 1980 | E | $5.4 \times 10^{8}$ | $3.3 \times 10^{6}$ | | Effluent Grey Water—Appearance: Grey water. Occasional egg, probably free-living. No known human parasites found. | |
| May 1980 | I | $1.7 \times 10^{8}$ | $4.9 \times 10^{6}$ | | | |
| May 1980 | E | $5.4 \times 10^{8}$ | $3.3 \times 10^{7}$ | | Effluent Grey Water—Appearance: Grey water. No parasites found. No known human parasites found. | |
| June 1980 | I | $9.2 \times 10^{8}$ | $\geqslant 2.4 \times 10^{8}$ | | | |
| June 1980 | E | $1.6 \times 10^{9}$ | $6.3 \times 10^{6}$ | | | |
| **Influent (I)**<br>Geometric Mean<br>Range<br>N = | | <br>$3.1 \times 10^{8}$<br>$10^{7} - 10^{9}$<br>6 | <br>$5.5 \times 10^{6}$<br>$10^{5} - 10^{7}$<br>5 | | | |
| **Effluent (E)**<br>Geometric Mean<br>Range<br>N = | | <br>$4.1 \times 10^{8}$<br>$10^{7} - 10^{9}$<br>6 | <br>$1.1 \times 10^{7}$<br>$10^{6} - 10^{7}$<br>6 | | | |

## TABLE 2 UNIT 3: ANALYTICAL DATA

| SAMPLE |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | NO$_2$ mg/l | NO$_3$ mg/l | EC µmhos/cm |
| December 1979 | I | 6.9 | 330 | 780 | 580 | 220 | 10 | – | 0.5 | 600 |
| December 1979 | E | 6.6 | 380 | 330 | 580 | 80 | 10 | – | 0.4 | 680 |
| January 1980 | I | 6.8 | 320 | 800 | 330 | 120 | 10 | 0.2 | 0.6 | 380 |
| January 1980 | E | 7.2 | 200 | 320 | 340 | 80 | 10 | 0.1 | 0.5 | 430 |
| February 1980 | I | 8.6 | 180 | 390 | 530 | 60 | 10 | – | 0.4 | 520 |
| February 1980 | E | 7.4 | 200 | 390 | 540 | 70 | 20 | – | 0.4 | 140 |
| March 1980 | I | 6.0 | 540 | 690 | 400 | 130 | 10 | <0.1 | <0.1 | 460 |
| March 1980 | E | 6.5 | 350 | 360 | 520 | 70 | 10 | <0.1 | 0.6 | 560 |
| March 1980 | W | 7.3 | 2 | 2 | 240 | 4 | <0.3 | – | <0.1 | 320 |
| April 1980 | I | 6.7 | 210 | 350 | 290 | 100 | 10 | 0.1 | <0.1 | 380 |
| April 1980 | E | 6.5 | 290 | 280 | 400 | 50 | 10 | 0.1 | <0.1 | 470 |
| May 1980 | I | 6.6 | 4,900 | 7,400 | 910 | 1,900 | 60 | <0.1 | 1.6 | 250 |
| May 1980 | E | 7.1 | 830 | 1,300 | 810 | 440 | 10 | <0.1 | 0.2 | 410 |
| June 1980 | I | 6.1 | 800 | 1,400 | 420 | 450 | 5 | <0.1 | 2.5 | 350 |
| June 1980 | E | 7.1 | 200 | 420 | 420 | 30 | 10 | <0.1 | 1.3 | 590 |
| **Influent (I)** |  |  |  |  |  |  |  |  |  |  |
| Geometric Mean |  | 6.8 | 506 | 932 | 462 | 209 | 12 | – | 0.9 | 203 |
| Range |  | 6.0 – 8.6 | $10^2 - 10^3$ | $10^2 - 10^3$ | 290 – 910 | $10 - 10^3$ | 5 – 60 | <0.1 – 0.2 | 0.4 – 2.5 | 250 – 600 |
| N = |  | 7 | 7 | 7 | 7 | 7 | 7 | 5 | 5 | 7 |
| **Effluent (E)** |  |  |  |  |  |  |  |  |  |  |
| Geometric Mean |  | 6.9 | 307 | 419 | 497 | 130 | 11 | – | 0.5 | 427 |
| Range |  | 6.1 – 7.4 | 200 – 830 | $10^2 - 10^3$ | 340 – 810 | 30 – 440 | 10 – 20 | <0.1 – 0.1 | 0.2 – 1.3 | 140 – 680 |
| N = |  | 7 | 7 | 7 | 7 | 7 | 7 | 5 | 6 | 7 |

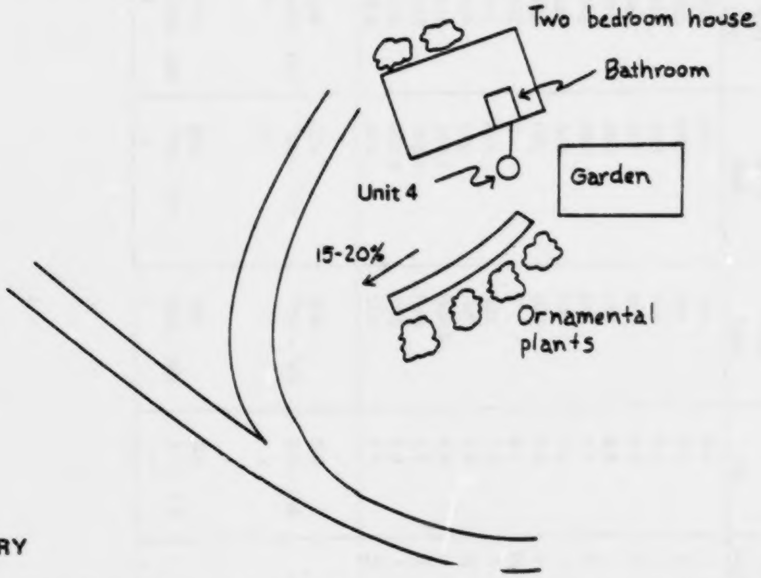
## UNIT 4

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Desert |
| Depth to Groundwater: | > 500 feet |
| Soil Percolation: | < 45 min./in. |
| Depth to Bedrock: | 3 feet |
| Slope: | 10 percent |
| Lot Size: | 5 acres |
| Other: | • Slope allows for gravity flow<br>• Septic tank–soil absorption system<br>• Public water system |

### UNIT DESIGN

| | |
|---|---|
| Type: | Grey water–no treatment |
| Size: | 30-gallon tank |
| Construction Material: | Metal tank, PVC piping |
| Ventilation: | Open air |
| Other: | • Tank surrounded on three sides with ornamental rocks<br>• Located 30 feet from house |



### SERVICE HISTORY

Owing to the dry climate the users installed the tank to hold the wastewater from the bath and washing machine prior to using for irrigation of flowers and trees. The grey water drains from the bath and washing machine to the holding tank where the user manually removes the wastewater by bucketful for irrigation of ornamental plants. Biodegradable soaps are used in all washings.

The users have been very satisfied with the unit and its operation.

## TABLE 1 UNIT 4: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| September 1979 | I | $4.9 \times 10^7$ | $2.0 \times 10$ | | | |
| September 1979 | I | $1.3 \times 10^5$ | $1.3 \times 10^2$ | | | |
| October 1979 | I | $1.3 \times 10^4$ | $4.9 \times 10^3$ | | | |
| November 1979 | I | $1.7 \times 10^5$ | $4.5 \times 10^2$ | | | |
| December 1979 | I | $3.3 \times 10^6$ | $2.0 \times 10$ | | | |
| January 1980 | I | $1.3 \times 10^4$ | $<2.0 \times 10$ | | | |
| February 1980 | I | $4.9 \times 10^5$ | $<2.0 \times 10$ | | | |
| March 1980 | I | $2.2 \times 10^4$ | $<2.0 \times 10$ | | | |
| April 1980 | I | $9.4 \times 10^3$ | $2.0 \times 10$ | | | |
| May 1980 | I | $4.9 \times 10^3$ | $<2.0 \times 10$ | Enterobacter cloacae<br>Citrobacter freundii | | None Isolated |
| June 1980 | I | $4.9 \times 10^3$ | $<2.0 \times 10$ | Enterobacter cloacae<br>Citrobacter freundii | | |
| **Influent (I)** | | | | | | |
| Geometric Mean | I | $8.4 \times 10^4$ | $5.2 \times 10$ | | | |
| Range | I | $10^3 - 10^7$ | $<10 - 10^3$ | | | |
| N = | I | 11 | 11 | | | |

# TABLE 2 UNIT 4: LIQUID DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC µmhos/cm |
| September 1979 | I | 7.4 | – | 70 | 140 | 510 | 70 | 10 | <0.9 | 840 |
| September 1979 | I | 7.3 | – | 550 | 770 | 640 | 400 | 20 | 0.2 | 700 |
| October 1979 | I | 7.9 | – | 50 | 60 | 500 | 30 | 2 | <0.4 | 720 |
| November 1979 | I | 6.8 | – | 130 | 250 | 550 | 280 | 10 | 1.1 | 770 |
| December 1979 | I | 7.3 | – | 70 | 440 | 640 | 400 | 20 | 0.9 | 750 |
| January 1980 | I | 7.2 | – | 170 | 650 | 480 | 100 | 10 | 0.1 | 600 |
| February 1980 | I | 7.1 | 0.07 | 60 | 280 | 490 | 60 | 3 | <0.1 | $1.1 \times 10^3$ |
| March 1980 | I | 7.6 | 0.02 | 40 | 120 | 420 | 20 | 4 | 0.1 | 440 |
| April 1980 | I | 8.5 | 0.02 | 130 | 330 | 930 | 80 | 11 | 17 | 950 |
| June 1980 | I | 8.7 | <0.02 | 160 | 230 | 630 | 70 | 14 | 3.3 | 840 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | I | 7.4 | 0.03 | 156 | 258 | 558 | 144 | 8 | 0.5 | 741 |
| Range | I | 6.8 – 8.7 | .02 – .07 | 40 – 550 | 60 – 770 | 420 – 980 | 20 – 400 | 2 – 20 | <0.1 – 17 | $600 - 1.1 \times 10^3$ |
| N = | I | 10 | 4 | 10 | 10 | 10 | 10 | 10 | 7 | 10 |

# UNIT 5

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Desert |
| Depth to Groundwater: | $>$ 500 feet |
| Soil Percolation: | $<$ 45 min./in. |
| Depth to Bedrock: | 0–3 feet |
| Drinking Water Source: | Public water system |
| Slope: | 20 percent |
| Lot Size: | 20 acres |

## UNIT DESIGN

| | |
|---|---|
| Type: | Collecting tank and surface hose |
| Size: | 60-gallon tank |
| Construction Material: | • Galvanized steel tank<br>• Plastic hose |
| Sources: | Laundry |
| Effluent Disposal: | Movable hose to landscape or pig pen |

## SERVICE HISTORY

This owner-built system was installed in 1978 just outside of an abandoned home which was slated for renovation. During the study it handled only laundry wastewater. Maintenance involved occasional removal of lint through a small (6"–8") access port on top of the drum.

## HIGHLIGHTS

The users reported no problems with odors or insects.

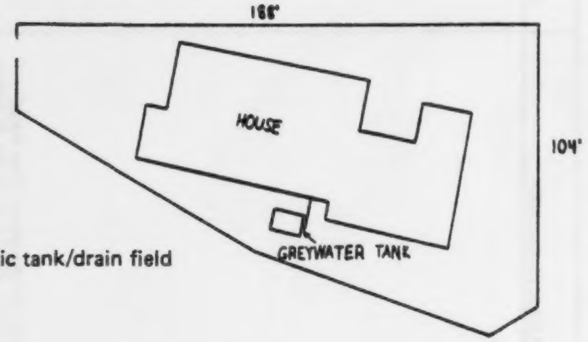
TABLE 1 UNIT 5: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| September 1979 | I | $<2.0 \times 10$ | $<2.0 \times 10$ | | | |
| October 1979 | I | $4.9 \times 10^3$ | $4.9 \times 10^3$ | | | |
| November 1979 | I | $2.2 \times 10^5$ | $7.9 \times 10^4$ | | | |
| December 1979 | I | $1.3 \times 10^4$ | $7.9 \times 10^2$ | | | |
| January 1980 | I | $2.3 \times 10^3$ | $<2.0 \times 10$ | | | |
| February 1980 | I | $4.9 \times 10^2$ | $<2.0 \times 10$ | | | |
| March 1980 | I | $3.3 \times 10^2$ | $<2.0 \times 10$ | | | |
| April 1980 | I | $1.1 \times 10^3$ | $2.0 \times 10$ | | | |
| June 1980 | I | $3.3 \times 10^3$ | $<2.0 \times 10$ | | | |
| **Influent (I)** | | | | | | |
| Geometric Mean | I | $3.4 \times 10^3$ | $1.6 \times 10^3$ | | | |
| Range | I | $10^2 - 10^5$ | $10 - 10^4$ | | | |
| N = | I | 8 | 4 | | | |

TABLE 2 UNIT 5: ANALYTICAL DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| September 1979 | I | 8.8 | 100 | 280 | 680 | 130 | 10 | – | 4.1 | 900 |
| October 1979 | I | 7.9 | 190 | 1,300 | 730 | 1,500 | 20 | – | $<0.4$ | 810 |
| November 1979 | I | 7.5 | 40 | 170 | 490 | 150 | 10 | – | 2.0 | 700 |
| December 1979 | I | 8.8 | 70 | 360 | 570 | 320 | 10 | – | 1.8 | 1,200 |
| January 1980 | I | 8.7 | 110 | – | 680 | 370 | 20 | – | 0.4 | – |
| February 1980 | I | 8.9 | 40 | 630 | 710 | 140 | 10 | 1.7 | 7.5 | 1,500 |
| April 1980 | I | 8.1 | 100 | 80 | 580 | 60 | 10 | $<0.1$ | 0.5 | 580 |
| June 1980 | I | 9.2 | 50 | 220 | 780 | 60 | 5 | $<0.1$ | $<0.1$ | 970 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | I | – | 76 | 305 | 646 | 191 | 11 | – | – | – |
| Range | I | | 40 – 190 | 80 – 1,300 | 490 – 780 | 60 – 1,500 | 6 – 20 | | | |
| N = | I | | 8 | 7 | 8 | 8 | 8 | | | |

# UNIT 6

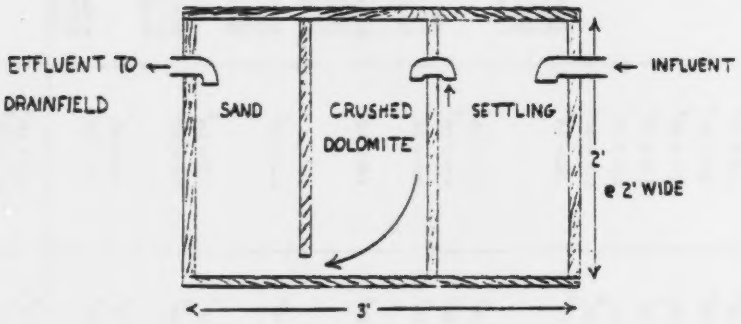

188'
104'
HOUSE
GREYWATER TANK

## SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | > 5 feet |
| Soil Percolation: | < 10 min./in. |
| Depth to Bedrock: | 0–2 feet |
| Slope: | 40–45 percent |
| Lot Size: | .23 acre |
| Other: | • Sewage treatment by septic tank/drain field<br>• Public water system |

## UNIT DESIGN

| | |
|---|---|
| Type: | Slow sand filter |
| Size: | 2' D x 3' L x 2' W; 90 gallon volume |
| Construction Material: | • Redwood 2" x 10"<br>• Crushed dolomite<br>• Sand |
| Sources: | Shower/sinks/dishwasher |
| Effluent Disposal: | Subsurface 25' leach line to flower garden |
| Other: | Three chambers: (1) settling, (2) crushed dolomite, (3) sand |


EFFLUENT TO
DRAINFIELD
SAND
CRUSHED
DOLOMITE
SETTLING
INFLUENT
2'
e 2' WIDE
3'

## SERVICE HISTORY

This grey water system was installed in May 1979, and has accommodated 2–3 regular users with occasional guests. The users have washed the rocks twice.

## HIGHLIGHTS

The users reported no problems with odors, insects or clogging in their system. An initial problem with overflow was corrected with an enlarged outlet pipe; the users suggested bottomless chambers for liquid disposal.

## TABLE 1 UNIT 6: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | I | $2.4 \times 10^9$ | $3.3 \times 10^5$ | | | |
| August 1979 | E | $2.3 \times 10^9$ | $7.9 \times 10^3$ | | | |
| September 1979 | I | $2.8 \times 10^6$ | $1.3 \times 10^5$ | | | |
| September 1979 | E | $3.3 \times 10^6$ | $3.3 \times 10^4$ | | | |
| October 1979 | I | $3.5 \times 10^8$ | $1.3 \times 10^6$ | | | |
| October 1979 | E | $1.4 \times 10^2$ | $1.4 \times 10^2$ | | | |
| November 1979 | I | $4.9 \times 10^6$ | $2.3 \times 10^5$ | | | |
| November 1979 | E | $4.9 \times 10^6$ | $3.3 \times 10^5$ | | | |
| December 1979 | I | $1.4 \times 10^6$ | $3.3 \times 10^5$ | | | |
| December 1979 | E | $7.9 \times 10^6$ | $1.4 \times 10^6$ | | | |
| January 1980 | I | $4.9 \times 10^7$ | $1.3 \times 10^7$ | | | |
| January 1980 | E | $2.8 \times 10^4$ | $1.7 \times 10^4$ | | | |
| February 1980 | I | $1.1 \times 10^7$ | $7.9 \times 10^5$ | Enterobacter cloacae<br>Citrobacter freundii<br>Enterobacter aerogenes<br>Klebsiella oxytoca<br>Pseudomonas acruginosa | | |
| February 1980 | E | $2.3 \times 10^6$ | $1.3 \times 10^5$ | | | |
| March 1980 | I | $2.1 \times 10^6$ | $4.9 \times 10^5$ | | | |
| March 1980 | E | $2.2 \times 10^5$ | $4.9 \times 10^4$ | Citrobacter freundii<br>Proteus morganii | Effluent Grey Water—Appearance: Grey liquid. Many free-living ciliates, occasional larvae, probably free-living. No known human parasites found. | |
| April 1980 | I | $3.3 \times 10^6$ | $7.0 \times 10^3$ | Serratia Liquefaciens<br>Klebsiella pneumoniae<br>Citrobacter freundii<br>Pseudomonas cepacia<br>Escherichia coli | Influent Grey Water—Appearance: Grey water. Many free-living ciliates and flagellates. Few larvae, probably free-living. Occasional mite egg. No human parasites found. | |
| April 1980 | E | $1.4 \times 10^6$ | $3.1 \times 10^2$ | Aeromonas hydrophila<br>Klebsiella pneumoniae<br>Citrobacter freundii<br>Pseudomonas cepacia | Effluent Grey Water—Appearance: Grey water. Few free-living flagellates. No known human parasites found. | |
| May 1980 | I | $3.5 \times 10^7$ | $3.3 \times 10^6$ | | | |
| May 1980 | E | $7.9 \times 10^5$ | $7.9 \times 10^4$ | Proteus morganii<br>Citrobacter freundii<br>Klebsiella pneumoniae | Effluent Grey Water—Appearance: Grey water. Many ciliates, occasional larvae, probably free-living. No known human parasites found. | None Isolated |
| June 1980 | I | $7.0 \times 10^7$ | $3.3 \times 10^7$ | | | |
| June 1980 | E | $3.9 \times 10^5$ | $7.9 \times 10^4$ | Klebsiella pneumoniae<br>Enterobacter cloacae<br>Citrobacter freundii | Effluent Grey Water from Sand Filter—Appearance: Grey water. Occasional larvae, probably free-living. Occasional ciliate. No known human parasites found. | |
| Influent (I) Geometric Mean | | $1.9 \times 10^7$ | $6.9 \times 10^5$ | | | |
| Range | | $10^6 - 10^9$ | $10^5 - 10^7$ | | | |
| N = | | 11 | 11 | | | |
| Effluent (E) Geometric Mean | | $8.8 \times 10^5$ | $2.6 \times 10^4$ | | | |
| Range | | $10^2 - 10^9$ | $10^2 - 10^6$ | | | |
| N = | | 11 | 11 | | | |

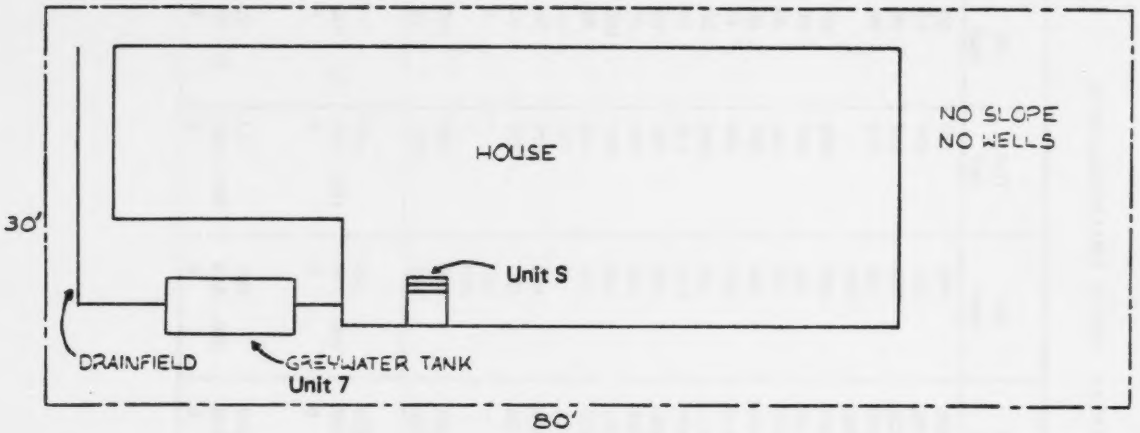
## TABLE 2 UNIT 6: ANALYTICAL DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC µmhos/cm |
| August 1979 | I | 6.5 | – | 300 | 530 | 370 | 50 | 10 | 1.7 | 300 |
| August 1979 | E | 6.8 | – | 210 | 390 | 370 | 10 | 10 | 1.4 | 370 |
| September 1979 | I | 7.1 | – | 230 | 300 | 540 | 80 | 10 | 0.4 | 520 |
| September 1979 | E | 6.9 | – | 230 | 340 | 470 | 80 | 10 | 0.3 | 510 |
| October 1979 | I | 6.1 | – | 260 | 610 | – | – | – | – | 900 |
| October 1979 | E | 6.9 | – | 190 | 430 | 690 | 50 | 10 | $<0.4$ | 900 |
| November 1979 | I | 6.3 | – | 90 | 260 | 230 | 60 | 10 | 0.4 | 370 |
| November 1979 | E | 6.6 | – | 120 | 320 | 350 | 80 | 10 | 1.0 | 520 |
| December 1979 | I | 6.9 | – | 170 | 280 | 280 | 80 | 10 | 0.2 | 370 |
| December 1979 | E | 6.8 | – | 210 | 340 | 450 | 40 | 10 | 0.7 | 590 |
| January 1980 | I | 6.9 | – | 470 | 770 | 340 | 90 | 10 | $<0.1$ | 380 |
| January 1980 | E | 7.3 | – | 300 | 510 | 420 | 30 | 10 | $<0.1$ | 500 |
| February 1980 | I | 6.4 | – | 200 | 440 | 190 | 80 | 10 | 1.4 | $2.5 \times 10^3$ |
| February 1980 | E | 6.7 | – | 260 | 410 | 300 | 20 | 10 | 0.9 | $3.3 \times 10^3$ |
| March 1980 | I | 6.6 | – | 240 | 540 | 350 | 100 | 10 | 0.4 | 380 |
| March 1980 | E | 7.0 | – | 220 | 260 | 520 | 80 | 10 | 1.0 | 560 |
| March 1980 | W | 7.7 | – | $\leq 1$ | 1 | 130 | 20 | $<0.2$ | 2.2 | 230 |
| April 1980 | I | 7.1 | – | 270 | 100 | 270 | 90 | 10 | 0.6 | 380 |
| April 1980 | E | 7.2 | – | 130 | 220 | 260 | 10 | 10 | 0.2 | 1,660 |
| May 1980 | I | 6.2 | – | – | 500 | – | – | – | $<1.0$ | 440 |
| May 1980 | E | 6.5 | – | – | 240 | – | – | – | $<1.0$ | 740 |
| June 1980 | I | 6.0 | – | 380 | 450 | 380 | 120 | 10 | $<1.0$ | 540 |
| June 1980 | E | 6.5 | – | 200 | 120 | 480 | 30 | 10 | $<1.0$ | 690 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | | 6.6 | – | 228 | 198 | 307 | 77 | 10 | 0.5 | 517 |
| Range | | 6.1 – 7.1 | – | 90 – 470 | 100 – 770 | 190 – 540 | 50 – 100 | 10 | $<0.1 - 1.4$ | $300 - 2.5 \times 10^3$ |
| N = | | 9 | – | 9 | 9 | 8 | 8 | 8 | 8 | 8 |
| **Effluent (E)** | | | | | | | | | | |
| Geometric Mean | | 6.9 | – | 212 | 203 | 433 | 40 | 10 | 0.6 | 684 |
| Range | | 6.6 – 7.3 | – | 120 – 310 | 260 – 510 | 300 – 690 | 10 – 80 | 10 | $<0.1 - 1.4$ | $380 - 3.3 \times 10^3$ |
| N = | | 8 | – | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

## UNIT 7

### SITE DESCRIPTION

| | |
|---|---|
| Climate: | Coastal |
| Depth to Groundwater: | 3½–4 feet |
| Soil Percolation: | 1 min./in. |
| Drinking Water Source: | Public water supply |
| Slope: | 0 percent |
| Lot Size: | 1/20 acre |
| Other: | • System located in backyard<br>• House is a rental with fluctuating use<br>• Sandy soil<br>• One block from ocean |



### UNIT DESIGN

| | |
|---|---|
| Type: | Grey water tank and leach field (converted septic tank system) |
| Size: | 7' x 4' x 3'; 630 gallons |
| Construction Materials: | Concrete, redwood top |
| Sources: | Kitchen/bathroom sinks, washing machine and shower (less than 100 gpd) |

### SERVICE HISTORY

The septic system was installed more than 20 years ago, but has been used as a grey water system since October 1978 when a small box-like humus toilet was installed.

The number of full-time users at this rental property has been estimated to be two with two additional users in the summer. Monthly unit inspections were made by representative of on-site waste management district.

### HIGHLIGHTS

A slight (1") scum layer was reported by the sanitarian. A leaching problem in the disposal field was reported by the owners who attributed the trouble to a high groundwater level, and proximity to ocean.

## TABLE 1 UNIT 7: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| August 1979 | I | $3.3 \times 10^5$ | $3.3 \times 10^3$ | | | |
| September 1979 | I | $2.3 \times 10^6$ | $7.9 \times 10^3$ | | | |
| October 1979 | I | $3.1 \times 10^4$ | $2.0 \times 10$ | | | |
| November 1979 | I | $1.7 \times 10^8$ | $3.3 \times 10^6$ | | | |
| December 1979 | I | $7.9 \times 10^7$ | $7.9 \times 10^7$ | | | |
| January 1980 | I | $3.3 \times 10^7$ | $2.3 \times 10^7$ | | | |
| February 1980 | I | $4.9 \times 10^7$ | $7.9 \times 10^6$ | | | |
| March 1980 | I | $3.3 \times 10^7$ | $1.1 \times 10^7$ | | | |
| April 1980 | I | $1.8 \times 10^6$ | $1.3 \times 10^5$ | | | |
| **Influent (I)** | | | | | | |
| Geometric Mean | | $6.2 \times 10^6$ | $3.2 \times 10^5$ | | | |
| Range | | $10^4 - 10^8$ | $10 - 10^7$ | | | |
| N = | | 9 | 9 | | | |

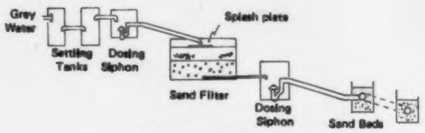
## TABLE 2 UNIT 7: ANALYTICAL DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| August 1979 | I | 6.7 | 160 | 210 | 300 | 40 | 20 | – | 0.6 | 430 |
| September 1979 | I | 6.0 | 230 | 250 | 330 | 100 | 20 | – | 0.2 | 450 |
| October 1979 | I | 6.4 | 100 | 190 | 300 | 70 | 20 | – | <0.4 | 470 |
| November 1979 | I | 6.2 | 160 | 430 | 400 | 190 | 90 | – | 0.6 | 1,200 |
| December 1979 | I | 6.8 | 720 | 1,600 | 360 | 780 | 90 | – | 3.7 | 920 |
| January 1980 | I | 6.6 | 330 | 620 | 340 | 110 | 40 | – | <0.1 | 650 |
| February 1980 | I | 6.8 | 190 | 300 | 370 | 60 | 30 | – | 0.6 | 1,500 |
| March 1980 | I | 6.5 | 260 | 340 | 370 | 150 | 20 | – | 0.6 | 430 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | | 6.5 | 226 | 380 | 345 | 119 | 33 | – | 0.9 | 673 |
| Range | | 6.0 – 6.8 | 100 – 720 | $190 - 1.6 \times 10^3$ | 300 – 400 | 60 – 780 | 20 – 90 | – | 0.2 – 3.7 | $430 - 1.5 \times 10^3$ |
| N = | | 8 | 8 | 8 | 8 | 8 | 8 | – | 6 | 8 |

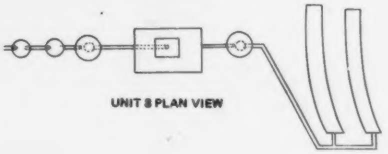
## UNITS 8 and 9

### SITE DESCRIPTION

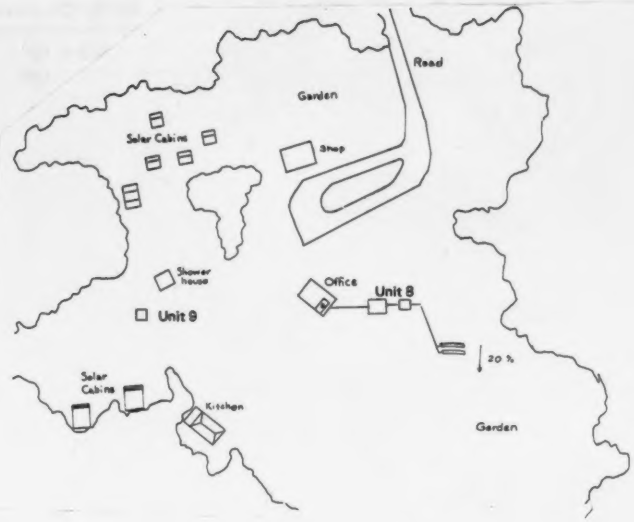
Climate: Coastal
Depth to Groundwater: 120 feet
Soil Percolation: 6–8 min./in.
Depth to Bedrock: > 4 feet
Slope: 20 Percent
Lot Size: 1 acre


Grey Water
Settling Tanks
Dosing Siphon
Splash plate
Sand Filter
Dosing Siphon
Sand Beds

UNIT 8 SECTION VIEW



UNIT 8 PLAN VIEW


Road
Garden
Solar Cabins
Shop
Shower house
Office
Unit 8
Unit 9
20 %
Solar Cabins
Kitchen
Garden

### UNIT 8 DESIGN

Type: Slow sand filter
Size:
- 15 square foot sand filter:
- 120 gallon, three chamber settling tank with 25 gallon dosing siphon to filter
- Designed for 75 gallons per day

Construction Materials: Redwood 2" x 4", plastic liner, river gravel, sand, PVC piping
Sources:
- Dairy kitchen, handwash and laundry sink

Effluent Disposal: Through 1" perforated PVC pipe, subsurface drip irrigation system in garden (see previous figure)

### UNIT 9 DESIGN

Type: Collection box with 25 gallon dosing siphon to subsurface leach field planted with berries
Construction Materials: Redwood 2" x 4", plastic liner, PVC piping
Sources: Communal bathroom with basin and shower
Effluent Disposal: Through 1" perforated PVC pipe, subsurface drip irrigation system in berry patch

### SERVICE HISTORY

This grey water system was installed in June 1979, and accommodated as many as two dozen users. Soaps and detergents (including phosphate and ammonia) were added to the system. No Borax (boron) or chlorine products were used. Unit 8 was used for six months per year and allowed to rest the other six months. The top 2" of sand were removed after the six-month use and composted in the garden compost pile. Unit 9 accommodated residents from solar cabin complex.

### HIGHLIGHTS

The users described their system as relatively trouble-free. An odor problem was traced to a box that was not tightly sealed. Accumulation and grease buildup was minimal in the system.

## TABLE 1 UNIT 8: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| August 1979 | I | $>2.4 \times 10^9$ | $4.6 \times 10^7$ | | | | |
| August 1979 | E | $>2.4 \times 10^9$ | $2.8 \times 10^7$ | | | | |
| September 1979 | I | $1.3 \times 10^7$ | $3.3 \times 10^6$ | | | | |
| September 1979 | E | $1.7 \times 10^6$ | $1.3 \times 10^5$ | | | | |
| October 1979 | I | $3.5 \times 10^8$ | $2.8 \times 10^7$ | | | | |
| October 1979 | E | $7.9 \times 10^6$ | $1.1 \times 10^6$ | | | | |
| November 1979 | I | $2.8 \times 10^5$ | $1.1 \times 10^3$ | Hafnia alvei<br>Enterobacter cloacae<br>Proteus morganii<br>Citrobacter freundii<br>Escherichia coli | Appearance: Cloudy, liquid specimen. Many ciliates, few larvae probably free-living. No known human parasites found. | None Isolated | |
| November 1979 | E | $1.3 \times 10^5$ | $3.3 \times 10^2$ | | | | |
| December 1979 | I | $1.3 \times 10^6$ | $4.9 \times 10^2$ | Citrobacter freundii<br>Hafnia alvei<br>Escherichia coli | Influent Grey Water—Appearance: Clear liquid with some white precipitate. Few live ciliates. No known human parasites found. | None Isolated | |
| December 1979 | E | $7.0 \times 10^4$ | $1.4 \times 10^2$ | | | | |
| January 1980 | I | $4.9 \times 10^3$ | $8.0 \times 10$ | | | | |
| January 1980 | E | $2.3 \times 10^4$ | $2.3 \times 10^2$ | | | | Site usage stopped 12/79 |
| February 1980 | I | $3.3 \times 10^3$ | $<2.0 \times 10$ | Citrobacter freundii<br>Aeromonas hydrophila | Influent Grey Water—Appearance: Clear liquid with some particles. Many flagellates, occasional ciliate, probably free-living. No known human parasites found. | | |
| February 1980 | E | $3.3 \times 10^3$ | $<2.0 \times 10$ | | | | |
| March 1980 | I | $1.7 \times 10^3$ | $<2.0 \times 10$ | Proteus morganii<br>Hafnia alvei<br>Klebsiella oxytoca<br>Citrobacter freundii | Grey Water—Appearance: Clear water with yellow flecks. Many free-living ciliates. No known human parasites found. | | |
| March 1980 | E | $2.3 \times 10^3$ | $<2.0 \times 10$ | Hafnia alvei<br>Aeromonas hydrophila<br>Klebsiella pneumoniae<br>Citrobacter freundii | Grey Water—Appearance: Clear water with particles of gray. Few ciliates, probably free-living, occasional mite egg, occasional larvae, probably free-living. No known human parasites found. | | |
| April 1980 | I | $3.3 \times 10^3$ | $<2.0 \times 10$ | | | | |
| April 1980 | E | $2.3 \times 10^4$ | $<2.0 \times 10$ | | | | May 1980 usage resumed |
| May 1980 | I | $4.9 \times 10^7$ | $2.3 \times 10^5$ | | | | |

TABLE 1 UNIT 8: MICROBIOLOGICAL DATA – Continued

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN | OTHER INFORMATION |
|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | |
| May 1980 | E | $2.8 \times 10^5$ | $6.3 \times 10^2$ | Aeromonas hydrophila<br>Enterobacter cloacae<br>Citrobacter freundii | Effluent Grey Water–Appearance: Grey water. Many ciliates and flagellates, probably free-living. Few larvae, probably free-living. No known human parasites found. | | |
| June 1980 | I | $9.2 \times 10^8$ | $4.9 \times 10^5$ | Proteus rettgeri<br>Proteus morganii<br>Enterobacter cloacae<br>Enterobacter aglomerans<br>Pseudomonas Aeruginosa | | | |
| June 1980 | E | $1.3 \times 10^7$ | $4.9 \times 10^3$ | | Effluent Grey Water from Sand Filter–Appearance: Grey water. Occasional larvae, probably free-living. Occasional ciliate. No known human parasites found. | | |
| **Influent (I)**<br>Geometric Mean<br>Range<br>N = | | <br>$1.3 \times 10^6$<br>$10^3 -> 10^9$<br>11 | <br>$1.0 \times 10^4$<br>$<10 - 10^7$<br>11 | | | | |
| **Effluent (E)**<br>Geometric Mean<br>Range<br>N = | | <br>$3.3 \times 10^5$<br>$10^3 -> 10^7$<br>11 | <br>$1.9 \times 10^3$<br>$<10 - 10^7$<br>11 | | | | |

## TABLE 2 UNIT 8: ANALYTICAL DATA

| SAMPLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | pH | $NO_2$ mg/l | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_3$ mg/l | EC µmhos/cm |
| August 1979 | I | 5.1 | – | 1,000 | 1,100 | 480 | 190 | 50 | 3.1 | 1,600 |
| August 1979 | E | 6.3 | – | 170 | 180 | 380 | 39 | 180 | 0.5 | 500 |
| September 1979 | I | 4.6 | – | >710 | 2,300 | 800 | 950 | 70 | 0.5 | 700 |
| September 1979 | E | 5.3 | – | >710 | 1,500 | 1,000 | 70 | 20 | 0.9 | 700 |
| October 1979 | I | 5.7 | – | 1,500 | 1,300 | 380 | 750 | 50 | 1.2 | 340 |
| October 1979 | E | 5.8 | – | 1,000 | 8,000 | 840 | 250 | 30 | 1.0 | 790 |
| November 1979 | I | 6.9 | – | <120 | 1,000 | 1,000 | 60 | 40 | 0.1 | 1,400 |
| November 1979 | E | 7.6 | – | 250 | 510 | 580 | 110 | 30 | 0.6 | 900 |
| December 1979 | I | 7.9 | – | 50 | 180 | 610 | 50 | 30 | 0.7 | 750 |
| December 1979 | E | 7.0 | – | 560 | 1,200 | 1,400 | 60 | 40 | 0.1 | 1,400 |
| January 1980 | I | 7.7 | – | <20 | 70 | 410 | 20 | 20 | 0.4 | 590 |
| January 1980 | E | 7.9 | – | <30 | 70 | 400 | 10 | 20 | 0.5 | 640 |
| February 1980 | I | 7.3 | – | 30 | 50 | 410 | 10 | 20 | 0.2 | 3,500 |
| February 1980 | E | 7.0 | – | 30 | 60 | 340 | 20 | 20 | 3.4 | 520 |
| March 1980 | I | 7.4 | – | 190 | 110 | 580 | 40 | 30 | 0.2 | $1.0 \times 10^3$ |
| March 1980 | E | 7.9 | – | 100 | 60 | 400 | 30 | 10 | 5.9 | 780 |
| April 1980 | I | 7.4 | – | 100 | 230 | 70 | 60 | 30 | 0.4 | 690 |
| April 1980 | E | 7.8 | – | 40 | 70 | 410 | 10 | 10 | 1.9 | 580 |
| June 1980 | I | 6.2 | – | 1,240 | 3,550 | 330 | 1,580 | 100 | <0.1 | 700 |
| June 1980 | E | 6.7 | – | 80 | 100 | 270 | 40 | 20 | 0.2 | 550 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | | 6.5 | – | 187 | 334 | 439 | 83 | 35 | 0.5 | $1.2 \times 10^3$ |
| Range | | 4.6 – 7.9 | – | 30 – 1,500 | $50 - 2.3 \times 10^3$ | $70 - 1.0 \times 10^3$ | 10 – 950 | 20 – 70 | 0.1 – 3.1 | $590 - 1.6 \times 10^3$ |
| N = | | 9 | – | 6 | 9 | 9 | 9 | 9 | 9 | 9 |
| **Effluent (E)** | | | | | | | | | | |
| Geometric Mean | | 6.9 | – | 161 | 306 | 564 | 39 | 26 | 0.9 | 721 |
| Range | | 5.3 – 7.9 | – | 30 – 1,000 | $60 - 8.0 \times 10^3$ | $340 - 1.4 \times 10^3$ | 10 – 250 | 10 – 180 | 0.1 – 5.9 | $580 - 1.4 \times 10^3$ |
| N = | | 9 | – | 7 | 9 | 9 | 9 | 9 | 9 | 9 |

## TABLE 1 UNIT 9: MICROBIOLOGICAL DATA

| SAMPLE | | TOTAL COLIFORM MPN/100 gm/ml | FECAL COLIFORM MPN/100 gm/ml | BACTERIA SCREEN | PARASITE SCREEN | VIRUS SCREEN |
|---|---|---|---|---|---|---|
| Date | Type | | | | | |
| September 1979 | I | $2.4 \times 10^9$ | $4.9 \times 10^3$ | | | |
| October 1979 | I | $3.5 \times 10^8$ | $2.3 \times 10^3$ | | | |
| November 1979 | I | $1.6 \times 10^9$ | $1.7 \times 10^3$ | | | |
| December 1979 | I | $1.6 \times 10^9$ | $2.3 \times 10^3$ | | | |
| January 1980 | I | $9.2 \times 10^8$ | $2.3 \times 10^3$ | | | |
| February 1980 | I | $1.7 \times 10^8$ | $3.3 \times 10^3$ | | | |
| March 1980 | I | $3.5 \times 10^8$ | $< 2.0 \times 10$ | | | |
| April 1980 | I | $5.4 \times 10^8$ | $7.9 \times 10^2$ | | | |
| May 1980 | I | $9.2 \times 10^8$ | $1.3 \times 10^6$ | | | |
| June 1980 | I | $1.8 \times 10^8$ | $4.9 \times 10^3$ | | | |
| **Influent (I)** | | | | | | |
| Geometric Mean | | $6.3 \times 10^8$ | $4.9 \times 10^3$ | | | |
| Range | | $10.8 - 10^9$ | $< 10 - 10^6$ | | | |
| N= | | 10 | 9 | | | |

## TABLE 2 UNIT 9: ANALYTICAL DATA

| SAMPLE | | pH | BOD mg/l | COD mg/l | TDS mg/l | SS mg/l | TOTAL N mg/l | $NO_2$ mg/l | $NO_3$ mg/l | EC µmhos/cm |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type | | | | | | | | | |
| September 1979 | I | 7.2 | 360 | 320 | 280 | 110 | 45 | – | 0.4 | 600 |
| October 1979 | I | 7.2 | 270 | 190 | 330 | 110 | 45 | – | 0.4 | 700 |
| November 1979 | I | 7.4 | 620 | 220 | 220 | 30 | 20 | – | 0.8 | 480 |
| December 1979 | I | 7.1 | 140 | 230 | 280 | 60 | 25 | – | 0.3 | 390 |
| January 1980 | I | 6.9 | 140 | 160 | 150 | 70 | 20 | – | 0.9 | 290 |
| February 1980 | I | 6.4 | 230 | 240 | 170 | 40 | 25 | – | 0.8 | 290 |
| March 1980 | I | 7.4 | 390 | 470 | 210 | 350 | 1 | – | 0.6 | 440 |
| April 1980 | I | 6.5 | 160 | 1,250 | 1,100 | 670 | 50 | – | 0.6 | 180 |
| May 1980 | I | 6.6 | 340 | 1,610 | 240 | 610 | 35 | – | 0.4 | 430 |
| June 1980 | I | 6.9 | 170 | 480 | 210 | 450 | 36 | – | 0.1 | 490 |
| **Influent (I)** | | | | | | | | | | |
| Geometric Mean | | 7.0 | 250 | 374 | 265 | 103 | 22 | | | |
| Range | | 6.5 – 7.4 | 140 – 620 | 160 – 1,610 | 150 – 1,100 | 30 – 670 | 1 – 50 | | | |
| N= | | 10 | 10 | 10 | 10 | 10 | 10 | | | |

# APPENDIX B

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Appendix B–1

## HEALTH EVALUATION COMMITTEE (HEC)

| MEMBER | EXPERTISE |
|---|---|
| Robert C. Cooper, Ph.D., Professor<br>School of Public Health<br>University of California, Berkeley<br>Committee Chairman | Microbial Infectious Disease |
| Clarence Golueke, Ph.D.<br>Research Microbiologist, Retired<br>Sanitary Engineering Research Lab | Solid Waste and Composting |
| Donald Heyneman, Ph.D., Professor<br>Department of Epidemiology and International Health<br>University of California, San Francisco | Parasitologist |
| Briar Cook, C.E.<br>Staff Environmental Engineer<br>United States Forest Service<br>San Dimas, California | Sanitary Engineer |
| L. Raynor Talley, R.S., M.P.H.<br>Director of Environmental Health<br>Santa Cruz County<br>Santa Cruz, California | Sanitarian |
| W. Wilson Sampson, Ph.D.<br>Health Biologist, Retired<br>Alameda County Health Care Services Agency<br>Oakland, California | Medical Entomologist |
| Richard E. Smith, R.S.<br>Director of Environmental Health<br>Humboldt-Del Norte County<br>Eureka, California | Sanitarian |
| Thomas H. Milby, M.D.<br>Medical Consultant<br>Environmental Health Associates<br>Berkeley, California | Physician |

## SUBJECTIVE ESTIMATE METHODS

All subjective methods of estimation depend upon an attempt to estimate and construct a subjective scale directly from the subject's own quantitative estimates of the scale values of a series of stimuli. To illustrate this point, the techniques used in a number of different fields familiar to most people (6) are listed in Table V–5.

### TABLE V–5. SUBJECTIVE ASSESSMENT TECHNIQUES USED IN VARIOUS FIELDS

| FIELD | TECHNIQUE |
|---|---|
| Psychophysics | methods of absolute judgment |
| Esthetics | rating methods |
| Personnel evaluation | rating methods |
| Education | essay scoring |
| Attitude scales | method of equal appearing intervals |

The techniques chosen for use in the study reported herein were the Delphi technique and a linear semantic scaling technique. A brief summary of the basic criteria that must be met by any testing device if it is to produce meaningful results is as follows:

A. The testing device must have validity. In the simplest of terms, validity in a testing device means that the instrument does, in fact, measure what it is supposed to measure. With respect to the present study, the method must provide an estimate of the public health risk posed to users of on-site systems. Compliance with this criterion is believed to have been met by:

  1. The use of a baseline on-site system that has a long history of use (i.e., septic tank system), and

  2. The estimation of risks for site-specific installations and general generic systems.

B. The testing device must be characterized by reliability. Accordingly, the measuring technique must be consistent. That is, assuming no change in the individual's actual attitude, the device must be consistent in repeated measurements. In the present study, compliance with this criterion was satisfied on the basis of the two techniques chosen.

Compliance with the following four criteria is not essential. Instead, it is dependent upon the decision maker's specific needs.

C. The third criterion is one of quantifiability. In some cases, qualitative (descriptive) data are all that are either required or are possible. In the study reported herein, an attempt was made to establish a quantitative estimate of on-site system use risk. It was felt that such information would aid the decision maker(s) in making sound judgments and that it would help in ensuring that regulations by local, state, or federal agencies would indeed reduce the most severe risks.

D. A fourth consideration is analysis potential. Analysis of the acquired data should be a simple process, and the data should lend themselves to computer manipulation. Based on the methodology for risk assessment and the subjective estimating techniques used in the present study, compliance with this criterion was relatively easy.

E. The fifth criterion, objectivity, implies two things: first, the technique should be free from constructor bias, Compliance in the present study was achieved by not constructing the measurement instruments with certain conditions or problems omitted. Not to do so would make the resulting data show a decided preference in the direction desired by the test designer. Secondly, objectivity in the general sense refers to the manner in which the measurement instrument is scored. In the present study, scoring methods were utilized in which simple instructions to the expert scorer were all that were required.

F. The sixth criterion, simplicity of administration, is self-explanatory. It was satisfied in the present study through the use of simple and self-administered measurement instruments.

In general, the six criteria for subjective estimating methods are met by the method of linear semantic scaling and the Delphi technique.

## DELPHI TECHNIQUE

The Delphi technique is a method of applying the collective knowledge or abilities of a diverse group of experts to the task of quantifying variables that either are intangible or are shrouded in uncertainty. In the present study, the Delphi technique was used to develop estimates of "P," i.e., the probability of a problem occurring. The term "expert," as defined by the developers of the technique (Rand Corporation), generally implies a highly educated and experienced specialist. For the purposes of the present study, an "expert" is defined as being a person knowledgeable about individual on-site waste disposal systems, and also as having an appreciation for research (the operational definition of expert).

The Delphi technique involves the use of a series of questionnaires designed to produce group consensus and to eliminate face-to-face confrontation as is experienced in panels or committees. The key characteristics of the Delphi approach are anonymity, controlled feedback, and statistical group response. Anonymity is attained through the use of questionnaires. In this way is avoided the effect of an undue influence of dominant panel members upon the responses of other panel members. Controlled feedback is attained by conducting the exercise in a sequence of rounds, between each of which a summary of the results of the previous round is communicated to the participants. The effect is a reduction in "noise." Use of the statistical group response reduces group pressure for conformity and assures that the opinion of every member is represented in the final response.

The procedure suggested for use in the present study consisted of three rounds:

Round I: Estimation of probability of occurrence of public health problem by first group.

Round II: Response to the same questionnaire, with a statistical summary of Round I responses.

Round III: Review summary of Round II responses based on review of site-specific system maintenance practices.

The form shown in Figure V–12 was used to solicit estimates of probability. A computer program was developed to accommodate the significant amount of data that would be generated.

## LINEAR (SEMANTIC) SCALING

A semantic scaling method was suggested for use in the development of estimates of "S," the severity of the problem. In this quantitative judgment approach, the respondent (physician) is required first to rank in order the public health problems (1 to 20) and then to scale each individual problem on a specified linear scale. In the present study, the linear scale ranged from 0 to 100.

Underlying assumptions inherent in the procedure are as follows:

A. The relative severity of a problem is made in comparison to the other problems being considered, and not to some absolute level of severity.

B. Severity judgments are medical opinions based on the physician's knowledge of life expectancy, degree of disability, and effectiveness of treatment of the public health problems under consideration.

C. The physician is assumed to make direct quantitative judgments as to the severity of each problem.

D. The physician's scaled (indicated) response is assumed to reflect the subjective value of the problem being scaled.

E. Any variation (over many respondents) in reporting is treated as being an error. This procedure results in the use of the mean of the responses as the best estimate of the scale value of each public health problem.

F. With the exception of the variation or error involved, the mean of the respondent's reporting is taken as the scale value of the problem on a linear continuum.

# ON-SITE WASTE TREATMENT AND DISPOSAL SYSTEMS DESCRIPTION

## BLACK WASTE SYSTEMS

### Pit Privy

A pit privy consists of a hand-dug or bored pit over which a shelter is placed for privacy. After the pit is filled, a new hole is dug and the structure is moved to a new site. Filled pits are covered with two feet or more of soil.

### Mouldering Toilet

"Mouldering" toilet is a term loosely applied to a broad group of self-contained (vault-type) toilet systems in which the addition of organic matter of plant origin to human excreta is a common characteristic. The group is divided into two principal subdivisions on the basis of whether or not aeration is accomplished passively or actively. Active aeration implies either forced aeration by mechanical means or the introduction of air by turning or equivalent mixing. A grey area in terms of definitions arises here. If the aeration is truly effective, the particular system may be validly designated as a "true compost" toilet. The beneficial features popularly associated with composting apply only to actively and effectively aerated systems.

### True Compost Toilet

The designation "true compost" toilet is given to a nonexistent dry toilet in which provision is made for the active control of the decomposition of raw human excreta into a sanitary soil amendment by exposure to indigenous microorganisms, heat, time, and sufficient oxygen in the presence of optimum moisture content. The control involves the provision of effective aeration, usually through "turning" the material. Effective aeration is indicated by: (1) rise in temperature of the composting mass, assuming the mass is sufficiently large to permit self-insulation (about one cubic yard) and (2) the absence of foul odors in the immediate vicinity of the composting mass. The final product from a "true compost" toilet is disposed of through burial and utilization as a soil amendment on landscape.

A factor common to the mouldering toilet and the "true compost" toilet is the need for handling when disposing of the final product.

## GREY WATER SYSTEMS

### Grey Water Definition

The term "grey water" is given to wastewater generated from the nontoilet plumbing fixtures in a residence, i.e., discharge from sinks, basins, bathtub, or shower, etc. Grey water may be used as irrigation water for edible food crops or for ornamentals and lawns.

### Septic Tank

The "septic tank" may be described as a watertight, covered receptacle designed and contructed: (1) to receive the discharge of sewage from a building sewer, (2) to separate solids from the sewage, (3) to digest the organic fraction of the solids through a period of detention, and (4) to allow the clarified liquids to be discharged for final disposal.

### Soil Absorption System

A soil absorption system is one in which the soil is utilized for the subsequent absorption of the treated sewage. The most common type of soil system consists of trenches lined with perforated pipe through which treated sewage seeps into the soil system. The pipes are placed in gravel and covered with earth.

## CONDITION DEFINITIONS

(1) **Climate:**

**Mountain**—(includes Northwestern Coastal Mountains) elevation over 2,500 feet; several areas receive over 60 inches of rain per year, with some receiving 70–110 inches per year; most areas receive 35–40 inches of rain per year; January average temperature 47°F; August average temperature 74°F; fog is rare; temperatures often exceed 100°F in July and August; above 3,000 feet the mountains have a forest cover with a mixture of several species of pine and other trees and many shrubs.

**Desert**—January average temperatures range between 46°–50°F; July average temperatures range between 93°–116°F; thunderstorms occur during the summer; rainfall averages around 1–10 inches per year.

**Coastal** (lowlands)—elevation below 2,500 feet; January temperatures average 54°F; July temperatures average 69°–74°F; coastal fog is a common occurrence in the summer and at times in the winter; rainfall averages between 10–35 inches per year; 85%–90% of the rain falls during the six winter months October through March; snow is rare; chaparral is the most widespread form of vegetation.

(2) **Density:** The following parameters have been grouped together in order to define density:

Total Number of Systems
Acres per System
Population Distribution (Age)
Number of People in System

The assumptions regarding the above parameters have been made yielding six density classifications.

| | DENSITY CLASSIFICATION | | | | | |
|---|---|---|---|---|---|---|
| | High (H) | | Medium (M) | | Low (L) | |
| PARAMETER | A | B | A | B | A | B |
| Total number of systems | < 20 | > 20 | < 20 | > 20 | < 20 | > 20 |
| Acres per system | < 1 | < 1 | 1–5 | 1–5 | > 5 | > 5 |
| Population distribution (Age) | ← NORMAL → | | | | | |
| Number of persons per system | ← 2.5 → | | | | | |

If there is no need to adjust the incremental risks, the total risk, $R_s$, can be calculated as follows:

$$R_s = \frac{\sum_{i=1}^{m} r_i}{\sum_{i=1}^{m} c} \qquad (5)$$

i = index of condition (1–m)
c = weight of condition (all equal to 1)

## ADDITIONAL RISK ASSESSMENT DATA

The first attempt at applying the risk assessment technique was made as part of this study (see Section 4.5) when an outside committee consisting of seven experts was convened.

The following results reported here are an expansion of that first group effort. Overall, 42 experts were interviewed relative to estimation of a problem occurring ($P_{ij}$ values). Table 1 provides a breakdown of the various fields which were represented. The term "expert" is defined as a highly educated and experienced specialist.

The severity of problem estimates ($S_j$) was originally developed by a group of five public health physicians. Based on these initial results, a random sampling of rural and urban physicians in California was conducted. A total of 2,500 questionnaires was mailed out with a return rate of 20 percent. Of those returned, 85.3 percent, or 428, were usable. Table 2 provides a summary of the severity values.

### TABLE 1 EXPERTS INTERVIEWED

| FIELD OF EXPERTISE | NUMBER INTERVIEWED |
|---|---|
| Public Health Microbiology | 7 |
| Virology | 3 |
| Sanitarian | 12 |
| Sanitary Engineer | 10 |
| Entomology | 8 |
| Parasitology | 2 |

Following equation 1 (see Section 4.5), the incremental risk values were calculated using the mean of $P_{ij}$ values and the mean $S_j$ values of Table 2. These incremental ($r_i$) values for all the disposal systems considered and for each condition are shown in Table 3. Using the results shown in Table 3 and following equation 2 (see Section 4.5), an estimate of the total system risk can be obtained. The results of the total risk (R) for the number of systems under similar conditions are shown in Table 4.

Estimates of the public health risk of combined black waste and grey water disposal systems are shown in Table 5. These estimates were made by calculating the composite event of the probability of a problem occurring when both systems are operative.

Review of the results indicates that with the exception of the grey water systems and the true compost toilet with solids disposal by burying the risk value increased by roughly an order of magnitude and the risk value for the true compost toilet with solids disposal through burying stayed the same.

**TABLE 2 MEAN SEVERITY VALUES OF PUBLIC HEALTH PROBLEM**

| PROBLEM | MEAN SEVERITY* |
|---|---|
| Infectious hepatitis | 83 |
| Encephalitis | 69 |
| *Salmonella* | 68 |
| *Shigella* | 64 |
| Typhoid | 64 |
| Enteric viruses | 62 |
| *Entamoeba histolytica* | 59 |
| Polio virus | 55 |
| *Giardia* | 48 |
| *Ascaris* | 43 |
| Hookworm | 40 |
| Cestodes | 37 |
| Nitrate | 36 |
| Rodents | 35 |
| Mosquitoes | 34 |
| Flies and gnats | 32 |
| Animal parasites | 26 |
| Venomous arthropods | 24 |
| Odor | 21 |
| Beetles | 15 |

* Relative linear scale of 0 to 100.

## TABLE 3 INCREMENTAL RISK VALUES ($r_j$) FOR EACH DISPOSAL SYSTEM UNDER A VARIETY OF CONDITIONS

| SYSTEMS<br>CONDITION<br>$i$ | Pit and Bury | Septic Tank Soil Absorption System | True Compost Toilet–Food Crop | True Compost Toilet–Landscape | True Compost Toilet–Bury | Mouldering Toilet–Food Crop | Mouldering Toilet–Landscape | Mouldering Toilet–Bury | Raw Grey Water–Food Crop | Raw Grey Water–Landscape | Grey Water to Septic Tank–Food Crop | Grey Water to Septic Tank–Landscape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Climate:** | | | | | | | | | | | | |
| Mountain | .4 | .3 | .4 | .3 | .2 | .5 | .4 | .2 | .3 | .3 | .3 | .2 |
| Desert | .2 | .1 | .3 | .2 | .1 | .3 | .3 | .2 | .2 | .2 | .2 | .2 |
| Coastal | .4 | .2 | .5 | .3 | .2 | .5 | .4 | .3 | .2 | .2 | .2 | .1 |
| **Groundwater:*** | | | | | | | | | | | | |
| < 3 feet | .4 | .3 | .4 | .3 | .3 | .4 | .3 | .3 | .3 | .2 | .2 | .2 |
| 3–5 feet | .4 | .2 | .3 | .2 | .2 | .3 | .3 | .3 | .2 | .2 | .2 | .1 |
| > 5 feet | .3 | .2 | .2 | .1 | .1 | .2 | .2 | .2 | .2 | .1 | .2 | .1 |
| **Soil Percolation:** | | | | | | | | | | | | |
| faster than 45 $\frac{\text{min.}}{\text{in.}}$ | .4 | .2 | .3 | .3 | .2 | .3 | .3 | .3 | .2 | .2 | .2 | .2 |
| 45–60 $\frac{\text{min.}}{\text{in.}}$ | .3 | .2 | .2 | .2 | .1 | .3 | .2 | .2 | .2 | .1 | .1 | .1 |
| slower than 60 $\frac{\text{min.}}{\text{in.}}$ | .2 | .1 | .2 | .2 | .1 | .3 | .2 | .2 | .1 | .1 | .1 | .1 |
| **Depth to Bedrock:** | | | | | | | | | | | | |
| < 4 feet | .3 | .2 | .3 | .3 | .2 | .3 | .3 | .3 | .2 | .1 | .2 | .1 |
| > 4 feet | .2 | .1 | .2 | .2 | .1 | .2 | .2 | .2 | .2 | .1 | .2 | .1 |
| **Topography Slope:** | | | | | | | | | | | | |
| 0–10 percent | .2 | .1 | .2 | .2 | .1 | .3 | .2 | .2 | .1 | .1 | .1 | .1 |
| 11–30 percent | .3 | .2 | .3 | .2 | .1 | .3 | .3 | .2 | .2 | .1 | .2 | .1 |
| > 30 percent | .4 | .2 | .3 | .3 | .2 | .4 | .3 | .2 | .2 | .2 | .2 | .2 |
| **Density:** | | | | | | | | | | | | |
| Low | .2 | .1 | .2 | .2 | .1 | .3 | .3 | .1 | .2 | .1 | .2 | .1 |
| Medium | .3 | .2 | .3 | .2 | .1 | .4 | .3 | .2 | .2 | .1 | .2 | .1 |
| High | .4 | .2 | .4 | .3 | .2 | .4 | .4 | .3 | .3 | .2 | .3 | .2 |

* Depth from ground surface; assume as potable water.

## TABLE 4 INCREMENTAL AND TOTAL SYSTEM RISK VALUES FOR DISPOSAL SYSTEMS UNDER SAME CONDITIONS

| SYSTEM | CONDITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | Coastal | Ground-water > 5 Feet | Soil Percolation 45–60 $\frac{\text{Min.}}{\text{In.}}$ | Depth to Bedrock: < 4 Feet | Slope 11–30 Percent | Density: Medium | Total System Risk R Probability of a Public Health Problem/System Life |
| Septic Tank Soil Absorption System | .2 | .2 | .2 | .1 | .2 | .2 | $3.2 \times 10^{-5}$ |
| True Compost Toilet to Bury | .2 | .1 | .1 | .1 | .1 | .1 | $2 \times 10^{-6}$ |
| True Compost Toilet to Landscape | .3 | .1 | .2 | .2 | .2 | .2 | $4.8 \times 10^{-5}$ |
| True Compost Toilet to Food Crop | .5 | .2 | .2 | .2 | .3 | .3 | $3.6 \times 10^{-4}$ |
| Mouldering Toilet to Bury | .3 | .2 | .2 | .2 | .2 | .2 | $9.6 \times 10^{-5}$ |
| Mouldering Toilet to Landscape | .4 | .2 | .2 | .2 | .3 | .3 | $2.9 \times 10^{-4}$ |
| Mouldering Toilet to Food Crop | .5 | .2 | .3 | .2 | .4 | .4 | $9.6 \times 10^{-4}$ |
| Raw Grey Water to Landscape | .2 | .1 | .1 | .1 | .1 | .1 | $2 \times 10^{-6}$ |
| Raw Grey Water to Food Crop | .2 | .2 | .2 | .2 | .2 | .2 | $6.4 \times 10^{-5}$ |
| Grey Water to Septic Tank to Landscape | .1 | .1 | .1 | .1 | .1 | .1 | $1 \times 10^{-6}$ |
| Grey Water to Septic Tank to Food Crop | .2 | .2 | .1 | .2 | .2 | .2 | $3.2 \times 10^{-5}$ |
| Pit Privy | .4 | .3 | .3 | .2 | .3 | .3 | $6.5 \times 10^{-4}$ |

Density: medium is defined as more than 20 systems, 1–5 acres per system, normal population distribution, and 2.5 persons per system.

## TABLE 5 ESTIMATE OF HEALTH RISK IN THE COMBINED DISPOSAL OF BLACK WASTE AND GREY WATER*

| BLACK WASTE SYSTEM | COMBINED RISK ESTIMATE | |
|---|---|---|
| | Raw Grey Water to Landscape | Raw Grey Water to Food Crop |
| Septic Tank Soil Absorption System | $3.2 \times 10^{-5}$ | |
| True Compost Toilet to Bury | $4 \times 10^{-6}$ | $6.6 \times 10^{-5}$ |
| True Compost Toilet to Landscape | $5 \times 10^{-5}$ | $1.1 \times 10^{-4}$ |
| True Compost Toilet to Food Crop | $3.6 \times 10^{-4}$ | $4.2 \times 10^{-4}$ |
| Mouldering Toilet to Bury | $9.8 \times 10^{-5}$ | $1.6 \times 10^{-4}$ |
| Mouldering Toilet to Landscape | $2.9 \times 10^{-4}$ | $3.5 \times 10^{-4}$ |
| Mouldering Toilet to Food Crop | $9.6 \times 10^{-4}$ | $1 \times 10^{-3}$ |
| Pit Privy | $6.5 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |

*Composite event of probability of a public health problem occurring with the black waste system or with the grey water system (i.e., $p(A \text{ or } B) = p(A) + p(B) - p(AB)$ where A and B represent the black and grey water systems respectively.

Analysis of the data indicates that the disposal system conditions of climate and population density play a predominant role in the determination of estimated risk values. Climate is considered a major variable since conditions of temperature, rainfall, and sunlight have a significant impact upon the survival and transport of disease agents that might be present in black waste or gray water. A desert climate was associated with the least risk, while mountains and coastal climates were felt to constitute a somewhat greater hazard. From the list of incremental risks shown in Table 3, it can be seen that the risk estimate tended to double when the system use conditions changed from low to high population density.

The degree of risk, as shown by these estimates, is heavily dependent upon the final use (disposal) of the black waste and grey water. As one might suspect, risk estimates increased in the following order: bury < landscape < food crop. This obviously reflects the experts' judgment concerning the mode of dose contact.

In making health risk estimates, the group of experts assumed that the on-site systems would be properly maintained. Thus, this factor was not a variable included as a system condition. During the conduct of the initial study, the group of seven experts indicated that the impact of poor maintenance would have a minor effect on public health risk values as long as systems were used in lightly populated areas. This means that improper maintenance may increase the risk to the individual involved in such maintenance activity, but the development of a public health problem as defined would most likely not occur.

The health risks associated with on-site waste treatment and disposal systems will vary with the disease morbidity in associated populations. Reported enteric infectious disease morbidity in the United States is generally low and, consequently, agent doses are low and dose contact limited. Thus, documented disease incidents associated with on-site systems are relatively rare events. Conditions outside the United States may be very different, especially in less developed and highly populated countries. Therefore, the values generated by this present exercise would not universally apply.

## Summary and Conclusions

Frequently judgment concerning the health risk associated with wastewater disposal alternatives must be made with an insufficiency of data. The risks assessment approach described herein is highly conducive to the formation of insights into the public health implications of disposal alternatives. The assessment method renders explicit the judgment of experts by recording the information used by them and the risk probability value assigned to a particular activity for the decision-maker's review. The methodology used is certainly subject to improvement. The risk values developed are by no means absolute probabilities but can serve as a useful tool in community planning and governmental review. The exercise tends to place potential health problems into a proper perspective and give one a sense of their magnitude.

# NEEDS SURVEY

## I. INTRODUCTION

The purpose of this Needs Analysis is to (1) determine and identify the concerns of local health officials regarding waterless toilets and grey water systems, and (2) discover the problems encountered by users of these systems. Once these concerns and problems are identified, they can be addressed in the Framework Development portion of the Education Program.

This analysis is based upon a survey of county health officials, a survey of system users, and a brief literature review. The survey of health officials was conducted in person by Storm Goranson, P.E., R.S., former Alameda County Public Health Engineer. Officials from seven different counties were interviewed. A copy of the questionnaire used appears in the appendix.

The users of waterless toilets and grey water systems were surveyed either by on-site visits or by mail. The questionnaires were developed by Storm Goranson and reviewed by Malcolm Walker, Project Director of the State Office of Appropriate Technology (OAT), and John Poorbaugh of the State Department of Health Services (DHS). Sixteen site visits were conducted by Mr. Goranson. Of the 30 questionnaires mailed out, 22 were returned (73 percent). The total response included nine Clivus Multrum users, five Toa Throne users, four Mullbank users, four Bioloo users, five Farallones vault users, two pit privy users, and two 55-gallon drum users. Responses were received from 7 out of the 11 grey water users (64 percent).

## II. NEEDS ANALYSIS

### A. Health Officials Concerns

Responsible health officials in seven counties were interviewed to ascertain basic public health concerns regarding the use of composting toilets and grey water systems. With the exception of two counties, all the officials felt that their Boards of Supervisors would adopt reasonable requirements for the use of these systems. Apparently, there is considerable pressure at the local level from citizens who wish to develop their land, but are stymied by public health regulations, money, and/or philosophical approaches.

All of the jurisdictions favoring these systems recommended the use of special districts to regulate and maintain the systems (provided that the health department oversees the program). It was believed that special districts would provide both the necessary assurances that the systems would be adequately maintained and would tax the user so that the general public does not "subsidize" the use of the systems. One jurisdiction recommended that private installers be certified and required to maintain systems that they install. Periodic monitoring and surveillance reports would be submitted (i.e., similar to swimming pool maintenance services). The majority of the jurisdictions were not especially concerned with incurred costs attributable to new regulations, but they desired an estimate of manpower and costs (including lab fees) on a per unit basis, as well as recommended surveillance and enforcement procedures.

There was much concern that systems should only be installed in "rural" areas, and that public health problems would be a function of system density.

Most of the jurisdictions desired a draft ordinance, but requested that it be written to give the health officer the authority to develop and modify the ordinance as necessary. A couple of jurisdictions stated that the problems that would be encountered in the use of the systems would be operation and maintenance type, and that there was no way in which appropriate regulations could be developed.

One jurisdiction was totally opposed to the use of the systems, while another said that the cost for adequate surveillance and enforcement would be too great a public burden to justify their use. These two jurisdictions also suggested that preparation of an EIR would be necessary since the approval of the systems could have a growth-inducing impact.

There was some opposition to utilizing extensive amounts of staff time for user training. Some felt that the proper avenue for training was through a local junior college, perhaps similar to a pool operator certification program like that offered in Santa Clara County. One jurisdiction desired a "check list" of the "pros and cons" of the use of these systems, while another was concerned that disagreeing jurisdictions could possibly be "beat on the head" with a state publication.

1. Construction and Installation

An immediate concern mentioned by nearly all jurisdictions was how a grey water system with subsurface disposal could properly operate in an area where a conventional leach field could not. A need was discussed for information concerning:

a. The size of the system versus the number of users,

b. The construction of systems with costs under $500, and

c. Design parameters in areas with either steep slopes, narrow soil mantle, and/or perched water.

Requests were also made for handouts describing plans for owner-built units. There was little concern for the proper construction of both composting and grey water systems if designs for operable systems are available, since adequate construction can be assured as a portion of the "permit" process. However, there was considerable concern that if units failed there would be no reasonable alternative available, and this could result in serious public health problems and "nasty" enforcement proceedings.

There was some concern in a couple of counties about allowing construction of these systems because it would contradict the Uniform Plumbing Code. This would allegedly raise havoc with local contractors, as well as create problems with enforcing the plumbing code. In addition, it was recommended that all systems be recorded on the parcel deed.

Performance standards were recommended because of ease of enforcement and because they are conducive to the development of creative and innovative approaches. On the other hand, one county recommended that vault size be specified as a function of the anticipated number of users.

Regarding approval of these systems, health officials had several concerns:

- "Wholesale" use of systems,
- Long-term operation characteristics,
- Adequate maintenance by second owner,
- Expense of regulation,
- Future availability of parts and access to distributors, and
- Reliability of owner-built systems.

2. Start-up and Composting

There are no concerns related to start-up operation, per se. However, virtually every health official was concerned with the capability of composting units to adequately compost their contents, and requested specific information on the effectiveness of the various composting units.

3. Maintenance

It was nearly unanimous among jurisdictions surveyed that systems could be properly maintained by those "in tune" with the philosophical approach associated with sound use of the systems, but that problems would be created by both those unfamiliar or unconcerned with the systems and "second" users. These jurisdictions suggested, by and large, that these problems would be resolved if the systems were maintained by a credible third party (e.g., a third district).

Jurisdictions requested detailed information be prepared showing:

a. Construction and operation and maintenance standards (including maintenance frequencies);

b. Recommended local health department surveillance procedures and frequencies; and

c. Recommended enforcement action.

In addition, this information should be detailed according to the type of unit (e.g., pit privy, drum privy, Farallones vault large and small proprietary systems).

There was very little concern about the operation of grey water systems other than a need for periodic grease and solids removal and the location of disposal.

Several jurisdictions requested performance standards, "trouble shooting" guidelines, and inspection forms.

4. Health Risk

Concern for excessive liquid accumulation in the composting units—especially the smaller, household units—was expressed. (In our field survey we noted that operators of 52 percent of the systems had experienced liquid buildup problems which occasionally resulted in the overflow of the system.

Concern was also expressed for the need to communicate the importance of proper waste handling and diseases that may occur if wastes are poorly handled.

All had concerns for the proper disposal of composted solids and grey water wastes.

5. Vector and Odor Control

None of the health officials queried expressed concern for vector or odor problems. There was an occasional mention that either occurrence would affect only the user, and they suggested that the user would take those actions necessary to prevent such problems.

6. Ultimate Disposal

All health officials expressed concern about the microbiological quality of grey water and composted wastes, and they are awaiting the results of the HEC study. By and large, the consensus was that the quality is poor, dictating underground disposal. There was considerable concern that substantial public health problems are directly related to the quality of these wastes and the method of their disposal. Their concerns must be resolved in this study. Generally, recommendations for disposal included subsurface discharge of grey water and use of composted wastes away from vegetable gardens.

## B. User Problems

This analysis is based upon (1) a brief literature review conducted to determine how alternative wastewater disposal systems are intended to work, and (2) a survey of users conducted to discover how the systems actually work and to receive comments from the users. In general, the users appear to be satisfied with their waterless toilets. When asked to rate the problems of odors, vectors, maintenance, liquid buildup, and disposal, all rated these potentially major problems as either controllable or no problem (with the exception of one overloaded unit). Grey water system users reported few problems and generally simple maintenance requirements.

With the broad range of toilet units available, potential users are in need of a description of the alternatives (including capacity, frequency of maintenance, power requirements, etc.) so that they are able to choose the system that most closely matches the needs of the household. Also, users should know the purposes of the major components within their systems so that they are able to understand the function of the units.

### 1. Construction and Installation

Plans for construction of various owner-built waterless toilets and grey water systems have already been published.[59, 60, 61, 62, 63] Most of these appear to be adequate, so there should be no reason to develop such plans in the education program. Copies of these designs could be reproduced as handouts for potential builders.

Instructions for the installation of proprietary units also seem to be adequate,[66, 67] although important considerations could be reiterated.

It may also be helpful to include user suggestions on additions that solve specific problems. For instance, overflow in the Farallones vault was corrected in one instance by adding a lip to the front of the vault. Leaks occurring between the top gasket and a 55-gallon drum were stopped with a silicone sealer. Another user suggested technical measures to decrease condensation in the vent pipe and thus cut down on liquid buildup.

Heat is a vital part of the composting process, and insulation of the composting chamber is effective in keeping heat in and shielding the chamber from cold weather. Thirty-nine percent of the units surveyed were insulated. It appears that information is needed describing how units can be insulated.

### 2. Start-up and Composting

The instructions for start-up that come with the various units appear to be adequate. Fifty-two percent of the users surveyed used more than one type of start-up material. There does not appear to be a correlation between type of start-up material and later problems (e.g., liquid buildup).

One of the most important functions of the education program will be to explain the biological principles of the composting process, especially carbon/nitrogen ratio. If users understand these principles, they will be more able to diagnose and resolve problems in their systems. Initially there may be more problems associated with the unit (e.g., odors, vectors, liquid buildup). New users should be aware that it may take some time before the unit operates consistently.

Liquid buildup seems to be a common problem; 52 percent of the users experienced it. It is equally common in all of the waterless toilet systems except the pit privy. Most of the users have found ways to control the problem; adding dry material was mentioned most often. An understanding of the composting process would help users deal with this problem, along with the knowledge about methods of liquid removal and urine separation.

A few substances may inhibit the composting process, and the education program should point these out. Large quantities of wood ashes or lime can be inhibitory,[68] although some users added ashes to control vectors. Some insecticide sprays also cause problems. One user reported spraying with a pyrethine-base compound and felt that she was left with a "dead" pile as well as dead insects; the pile took several months to "awaken."

### 3. Maintenance

Of the users surveyed, 70 percent felt that their maintenance efforts are very or moderately important to the proper functioning of their systems. All but one felt their efforts were adequate, even if they felt no effort was involved. Although most of the users appear aware of the importance of regular maintenance, this should be emphasized in the education program.

Regular maintenance for all the waterless toilet units (except the pit privy) includes periodic inspection of the pile to evaluate its condition, turning or mixing of the pile, cleaning air intakes and vents, and removal of composted end products. Our survey indicates that only the Bioloo and Farallones vault users turned or mixed the contents of their units. Clivus Multrum and Toa Throne owners should be instructed to occasionally spread out the most recent additions to the pile, in order to take full advantage of the composting space. It is not clear why all of the Mullbank users answered "never" to the mixing question when the unit is equipped with a spreader; perhaps the question was misinterpreted.

The equipment used in maintenance of the toilets should be clearly marked and used only for that purpose in order to avoid soil contamination and health risks.[62] Only 29 percent of the users have their equipment specially marked. The importance of doing this, along with the health reasons, should be explained.

The reason behind other maintenance tasks (e.g., inspection, cleaning of vents and air intakes) should also be explained. People tend to follow directions more closely if they know the reasons for them, instead of merely being told what to do.

The survey showed quite a bit of variation in the frequency of compost removal. This could indicate the need for some guidance in this area. But it could also indicate differences in loading rates.

### 4. Health Risks

Although studies indicate that many of the human pathogens are killed by the composting process,[64, 65] users need to understand that the end product is not safe and should be handled accordingly. Grey water and urine also contain pathogens,[60] and the need for proper disposal of these should be explained. The importance of disinfecting hands and equipment after turning or disposing of compost should be discussed.

The basic objective of the education program regarding health risks should be to make the user aware of the possibilities for disruption of personal and public health, and to make him or her cautious but not paranoid. One specific effort could be to prepare a list of "typical" pathogens in grey water and toilet residuals.

### 5. Vector Control

The users in our survey described their insect problems as "not too bad" (71 percent) or "no problem" (26 percent). Only one said it was "terrible," but that was only during the stabilization of the system (a Toa Throne). In general, the pests involved were primarily fruit flies in the proprietary systems (59 percent) and other household flies in the owner-built systems (55 percent). The difference is probably because the owner-built systems were located in outhouses (i.e., greater housefly potential) and kitchen garbage was not added to them (i.e., lesser fruit fly potential).

A broad range of controls was used (e.g., pest strips, sprays, sticky tapes, ashes), alone or together. Most were described as very or moderately effective. There is a need to discuss the various control methods and call attention to those that could be hazardous to the user or to the pile (e.g., some pesticide sprays).

Emphasis should be given to the importance of screening on all possible vector entities, as well as the effectiveness of a toilet seat seal. Both screens and seals were lacking in some of the units surveyed (no toilet seat seal, 32 percent; bathroom or outhouse not screened, 50 percent; vault not screened, 26 percent; vent pipe not screened, 17 percent).

The addition of fruit and fresh material such as grass clippings appears to often cause outbreaks of insects. Users should be aware of this, even though some fresh material is required with the Clivus Multrum and the Toa Throne. Perhaps users could experiment to find materials which cause lesser outbreaks.

### 6. Odor Control

Odors appear to be a minor problem. They occurred in 48 percent of the systems surveyed, but in 80 percent of these the problem was only occasional and usually easily controlled. Lack of maintenance is often the problem, and therefore better maintenance is often the cure. The user who understands this will have a good incentive to maintain his or her system properly!

Users should also understand the principles and importance of air flow and proper venting, as they are critical to the evaporation needed.[60, 63, 68] Increased use of the vent fan often improves the air flow and eliminates odors. Elimination of liquid buildup and addition of dry material are also effective controls.

### 7. Ultimate Disposal

Information on this subject will be influenced by the results of the HEC study and by decisions of local health officials. If the compost end product is deemed safe for garden use, users should understand on which plants it can be used (ornamentals and fruit trees), and how to apply it (dug into trenches between plants, not applied as a top dressing). They also need to known if the compost from their type of system should go into the garden compost pile for further "cooking." (The need for this varies by system.)

If the end product cannot be used in the garden, but can be buried on-site, guidelines as to burial place and depth should be provided. If disposal is to be in an off-site landfill, perhaps county-wide collection services could be provided.

## III. RECOMMENDATIONS

The following recommendations summarize the findings of the preceding Needs Analysis. These recommendations will form the basis of the Framework Development. All recommendations apply to both the sanitarians' and users' frameworks, with the exception of those in the regulation category.

### A. General

1. Describe the basic design of the systems studied, giving the purposes of the major components.
2. Discuss recommended number of users for the various classifications of units.

### B. Construction and Installation

1. Obtain construction plans for owner-built systems including: (a) Farollones composting vault, (b) drum privy, (c) pit privy, and (d) grey water systems utilizing a grease trap with sand filtration (excluding leach field).
2. Discuss specific design methods to (a) separate urine, and (b) eliminate excessive liquid buildup in composting units.
3. Describe modifications made by users to improve the functioning of their systems.
4. Develop design parameters for the use of grey water systems in areas with steep slopes, narrow soil mantle, and perched water.
5. Point out important considerations in the installation of proprietary systems.

### C. Start-up and Composting

1. Make brief comments on the importance and reasons for a proper start-up.
2. Present a brief discussion of the composting process including recommended nitrogen and carbon ratios.
3. Prepare a list of do's and don'ts of composting.
4. Discuss temporary "shock load" measures (e.g., spare pit privy).

### D. Maintenance and Operation

1. Develop maintenance and inspection schedules for the following systems: (a) small box-like humus toilets, (b) large sloped fiberglass toilets, (c) large, sloped plastic toilets, (d) drum privies, (e) pit privies, (f) Farollones composting vault toilets, and (g) grey water systems utilizing a grease trap and sand filtration with subsurface disposal.
2. Briefly discuss basic problems that can occur if routine maintenance is not provided.
3. Discuss effectiveness of the operation of the various systems. Summarize reoccurring problems for various units. Include types of failures anticipated as well as mitigation measures.
4. Discuss problems associated with O & M by second owners and "nonbuilders."

E. **Health Risks**

1. Prepare table showing typical pathogens that may be associated with compost residue and grey water, and related illnesses.
2. Recommend handling procedures. Discuss disease potential related to improper handling.

F. **Vector Control**

1. Describe various means of vector exclusion and control for composting units, and reiterate their personal and public health significance.
2. Describe various sources of vector problems with recommendations for proper equipment, screening, and maintenance.
3. Prepare a list of various vectors found associated with units during study.

G. **Odor Control**

Discuss typical odor problems and causes, and necessary controls and mitigation factors.

H. **Ultimate Disposal**

Recommend disposal procedures and location for composting residue and grey water.

I. **Regulation**

1. Determine viability of having systems regulated and maintained by a special district; include the initial development of a special district, and discuss "pros and cons" of the various district structure, and necessary legal authority and technical ability.
2. Discuss feasibility of having private party perform periodic surveillance of systems.
3. Develop recommended surveillance program including observation frequency and details. Include checklist.
4. Discuss recommended enforcement actions needed to ensure the sound operation of these systems.

## SYNOPSIS OF HEALTH OFFICIALS' CONCERNS
## GREY WATER/COMPOSTING TOILETS EDUCATION STUDY

1. *WHAT PROBLEMS DO YOU FORESEE WITH THE OPERATION AND/OR CONSTRUCTION OF THESE UNITS?*

### COMPOSTING TOILETS

**County 1:**

A. Acknowledges that these units can be operated successfully by any party with an interest to do so and primary concern is with amateur operators and those not in tune philosophically to the operation of composting toilets.

B. Primary concern is disposal method and location, concerned about existence of pathogens and parasites in residuals from composting units.

C. Recommend use of special districts or Homeowner Association with the proper powers and technical abilities. Especially concerned with "wholesale" use of these kinds of systems, e.g., developers building subdivision homes in areas with inadequate soil to preclude use of septic tanks. Also is concerned with operations of such systems by homeowners.

D. Concerned with safety of finished product, especially for "wholesale" use.

E. If system fails, what aleternative does the homeowner have to use?

F. Composting toilets can only handle black water wastes and does nothing to treat/dispose of grey water wastes.

G. Construction is no problem since it can be monitored during permit and early construction processes.

**County 2:**

A. Opposed to the use of composting toilets especially in urban and urban-fringe areas. May have some use in rural areas.

B. Allows a double standard in that it contradicts uniform plumbing code.

C. Creates public health problems.

**County 3:**

A. Too limited information to make a sound decision.

B. Information should be collected over a long period of time in order to make a sound decision.

C. Concerned that owners not dedicated to philosophy of system will create problems.

D. Legality of just approving proprietary-type systems suspect that owner-built systems have potential for creating more problems.

**County 4:**

A. O & M appears to be greater than earlier anticipated. System must be operated by very conscientious user.

B. Required high frequency of maintenance.

C. Concerned with liquid buildup problem and in some units this problem has been acute and liquid has built up and spilled over.

D. Construction is no problem. Need for simple construction standards and handout.

**County 5:**

A. Concerned about operation and maintenance.

B. Concerned about disposal of composted material.

C. Is not very concerned about construction provided that adequate construction standards and handouts are available.

**County 6:**

A. Concerned with safe operation and maintenance.

B. Concerned about disposal of contents.

C. Does not anticipate public health problems with operation and maintenance, but concerned with public health problems in the handling and disposal of the final products.

**County 7:**

A. Concerned with handling and disposal of sludge material; does not want used on vegetative crops.

B. Concerned with second owners' ability to operate and maintain system.

C. Not very concerned with O & M since units will be responsibility of people who live in homes and they will only hurt themselves by its poor use.

D. Recommend that all such systems be recorded on deed.

E. Not concerned so much with construction, but feels that designs won't be approved until it can be shown that specific design will operate in safe and efficient manner.

## GREY WATER SYSTEMS

**County 1:**

A. Particularly concerned with way grey water disposed and used.

B. Require grey water disposal be underground.

C. Concerned grey water systems in areas with poor percolation and high slopes and narrow soil mantle or any areas with perched water problems.

D. Mainly construction problems and concerns and there is little concern with operation and maintenance of the system.

E. Does have grey water system policy and no systems have been approved.

**County 2:**

A. Same concerns as those specified with composting toilets.

B. Foresees problems retrofitting existing homes.

C. Has difficulty making sound comments due to lack of training and background.

**County 3:**

A. Much less of problem than composting toilets.

B. Has allowed several systems to be installed.

C. Other problems.

**County 4:**

A. Concerning lack of public concern and knowledge concerning composition of grey water. The Public thinks grey water harmless and a wonderful natural resource. Not as hazardous as black water, but this county disagrees. In other words, the county is concerned with disposal and use of grey water.

B. Concerns that if an area is not suitable for leachate, then how can it be suitable for grey water.

C. Not familiar with various structure alternative, also not familiar with operation and maintenance of these systems and/or various construction techniques. Therefore, not able to contribute much to it.

**County 5:**

A. Concerned with misuse of these systems.

B. Needs standard designs for systems costing less than $500 for distribution to the public.

C. Concerned with disposal of grey water wastes.

**County 6:**

No experience; no comments.

**County 7:**

A. Concerned with disposal of grey water.

B. Concerned with relationship between the type of system and the type and frequency of maintenance.

C. Does not feel construction is a problem, per se.

2. *CAN ADEQUATE (BUT REASONABLE) REGULATIONS AND PROCEDURES BE IMPLEMENTED FOR THESE SYSTEMS? WHAT WOULD BE THE BEST WAY TO IMPLEMENT THEM?*

### COMPOSTING TOILETS

**County 1:**

A. Yes, reasonable regulations can be developed, yet there would be a lack of manpower to enforce the requirements. Low density areas, low fees, and high manpower costs. This implies inadequate manpower to enforce these regulations.

B. Regulations should be very specific in regards to the required construction and maintenance of the systems.

C. More or less currently prohibited and concerned with the adoption of these regulations which would allow these systems to be installed.

D. Concerned with what the alternative would be if the systems did not work. There are no guarantees for successful long-term use.

E. Highly recommend the use of a special district to regulate and maintain these systems.

**County 2:**

A. Does not feel adequate regulations could be adopted since element of concern is human control which is subject to variability.

B. Inadequate financial arrangements and resources would be a problem in the use of special district for these types of systems.

C. Concerned with disposal and lack of available space in dumps for disposal of this waste which gives problems despite what the regulations may say.

**County 3:**

A. Reasonable regulations can be adopted.

B. Suggest that regulations be adopted in a form that allows Health Officer to make necessary changes in an easy manner.

C. Recommend that regulations should specify the number of individuals per vault size.

D. Prefers "performance standards" and believes such standards create innovation of new and sound designs.

**County 4:**

A. Reasonable regulations can be developed and adopted for "rural" construction. Not sure about the use of systems in urban-type areas.

B. Must have legal entity that can handle construction and own end of these systems.

C. No faith in private party to maintain these systems. By private party means professional service to maintain these systems, is unrelated to public structure of any kind.

D. Recommends special district for these systems in urban areas.

**County 5:**

A. Regulations can be adopted and could cover construction, but regulations could not cover necessary operation and maintenance.

B. Allow use of proprietary large vault composting toilets on a conditional basis.

C. Does not support use of smaller units such as Mullbank and Bioloo.

**County 6:**

A. Regulations can be adopted for design and construction, but not for operation and maintenance of these systems.

B. Use of sound design will only guarantee sound construction, not necessarily needed for operation and maintenance of systems.

**County 7:**

A. Regulations can be adopted, but the cost would be very great and unreasonable to the taxpayer.

B. This does not subscribe to use of special district for these systems since the cost would be too great to the general taxpayer. The point is regulations could be adopted, but would it be economically feasible?

**GREY WATER SYSTEMS: Yes or No?**

**County 1:**

A. Yes, regulations could be adopted, but again there would be a lack of adequate manpower to enforce these regulations.

B. Problems arise with the separation of grease and who disposes of the grease. Subsurface disposal should occur.

C. Recommend the use of a special district to construct and maintain these types of systems.

**County 2:**

No Comments.

**County 3:**

A. Regulations can be adopted, but should specify subsurface disposal.

B. Specifics as to minimum size of the system depending on the number of users should be included.

C. For both grey water and composting toilets, reasonable alternatives to a special district would be a private service maintaining these systems such as a swimming pool service maintaining swimming pools.

**County 4:**

Same comments as for composting toilets with initial concern that the hazard of both systems is a function of population density.

**County 5:**

Regulations can be adopted. Primary concern is the construction of these units—which can be handled through the permit process.

**County 6:**

Not sure if reasonable regulations can be adopted since the problems that prohibit use of leach fields for black water systems would also prohibit use of subsurface grey water systems.

**County 7:**

Regulations can be adopted, but they should specify subsurface disposal. If different standards are adopted for surface disposal, they should be acceptable to R.W.Q.C.B.

### 3. *CAN ENFORCEABLE GUIDELINES BE DEVELOPED? IF SO, HOW?*

This question was deleted due to several factors:

A. This question was confusing.

B. The intent was not understood (the intent was covered by Question 2). Several of the departments made the comment that guidelines are guidelines and therefore could not be enforced!

4. *WHAT WOULD BE THE CONSEQUENCES AND IMPACTS IF THESE SYSTEMS WERE INSTALLED WITHIN YOUR JURISDICTION?*

**County 1:**

A. Depends on where the systems were installed. High density area would have no impact, but a cluster urban area and valuable watershed may be a problem.

B. Concerns with the use of compost on home vegetable gardens, cannot see the use of this material on the vegetable gardens when manure is readily available.

**County 2:**

A. It would endanger the public health in the community.

B. It would create nuisance problems.

C. Increase the government cost given the need for additional enforcement services.

**County 3:**

A. Take time to allow full implementation of these systems. Would allow limited number of systems in for a specified time in order to study the use of these systems and to determine applicable parcel size.

B. If the system allows increased density then this could create nuisance problems.

C. Do not expect any impact.

**County 4:**

A. Ease a lot of frustrations.

B. Eliminate a lot of hostilities.

C. More impact on higher density urban areas.

**County 5:**

A. If installed in rural areas only, it would not create public health hazards.

B. If no public health hazard, then the minimum lot size could be reduced.

C. Too early to tell what impacts would be.

**County 6:**

Several political implications. Tradespeople and Board of Supervisors would be concerned if systems were not maintained by special district. Consequences, at least if a large number of systems were allowed to go in. Too, might have problems with speculative developers.

**County 7:**

A. Public outcry against this.

B. Impact manpower.

C. Would create health problems and nuisance complaints. More acceptable to rural areas than urban areas.

5. *WOULD THE BOARD OF SUPERVISORS ADOPT REASONABLE REGULATIONS?*

**County 1:**

Yes, if recommended by the Health Department. A possibility that they would be opposed by local contractors since they would create a double standards condition. Likely to be approved in remote areas.

**County 2:**

No, Class "K" housing failed unanimously.

**County 3:**

The Board's decision would be based on the strength of the Health Official's convictions. Right now the Health Department would *not* support the adoption of these regulations. The Health Officer currently has authority to permit alternative systems. However, the Board of Supervisors is interested in the development of as many parcels as possible.

**County 4:**

Yes, the Board would adopt reasonable regulations. In fact, the Board is currently waiting for the Health Department to make a decision and to develop regulations for these types of systems. The Health Department is waiting for the termination of the study before it makes a decision.

**County 5:**

Yes, the Board of Supervisors would adopt regulations.

**County 6:**

Yes, the Board would adopt regulations, but the key word is reasonable. Conservative and liberal elements would like to see the development of acceptable requirements. However, requirements and regulations must encompass both grey water and composting toilets before the Board would consider adopting them.

**County 7:**

If is difficult to determine whether the Board would adopt these conditions as the makeup of the Board is continuously changing; it would be close. However, if the Board thought an EIR necessary (EIR cost = $25,000), it is unlikely the Board would be willing to adopt requirements since it would be unwilling to pay the cost of an EIR. This is what happened to the "K" Class housing.

6. *HOW MUCH ADDITIONAL MANPOWER WOULD YOU NEED TO ENFORCE AN ADEQUATE REGULATORY PROGRAM? WHAT WOULD YOUR ENFORCEMENT PROGRAM CONSIST OF? WOULD YOU WANT SUGGESTIONS?*

**County 1:**

Would not create much of a manpower problem. An estimate of approxiately ¼ additional man year.

**County 2:**

No comment.

**County 3:**

A. Yes, additional manpower required.

B. Need for ongoing test program.

C. Need for contract between user and installer for performance monitoring for a specified period of time.

D. Recommend development of forms for reports to be sent to the Health Department concerning the periodic monitoring of these units.

E. Majority of work performed by installer and user; no additional personnel.

F. Need for certification program to certify reliability of performance by installers.

**County 4:**

A. Yes, additional manpower to handle all systems.

B. However, to be similar to on-site systems with no immediate changes foreseen.

C. No inspection of on-site systems in rural areas, but there would be inspection in urban areas.

D. Recommend that special district be the permitting agency and would provide necessary operation and maintenance, and therefore the cost would not be shifted to Health Department.

**County 5:**

Perhaps additional manpower would be needed for composting toilets, yet unlikely.

**County 6:**

Improbable to answer for it's a function of how many units would be installed. Perhaps a study could estimate the number of manpower hours per unit and on a county-wide basis. In addition, travel time between environmental health units would vary county to county. Should be some recommendation for frequency of inspection, and a recommendation on how to resolve problems found during these inspections.

**County 7:**

Function of the number of systems and frequency of inspection. Additional costs such as lab costs should be included in the determination of the total cost of the reinforcement program.

7. *WHAT ISSUES SHOULD BE ADDRESSED IN THE "NEEDS ANALYSIS"?*

**County 1:**

A. Recommendation for handling compost material. Recommendation should be directed to users and must be very specific.

B. For grey water systems, a study should recommend soil conditioning and depth of soil mantle with specific construction standards including construction materials.

**County 2:**

A. Analyze growth-inducing aspects and discuss the need for EIR.

B. Minimum lot sizes as a function of the type of area.

**County 3:**

A. For proprietary systems, what happens if distributor or equipment is no longer available?

B. What happens when house is sold or rented?

C. What if there's a problem? What type of actions would be taken to enforce performance? What type of performance criteria?

**County 4:**

A. Need for specific construction standard and operation and maintenance standards.

B. Inability of systems to adequately compost provides potential for a health problem.

C. All systems should be operated by public entity, technically and financially capable of operating these systems.

D. Need to communicate to user the hazards of composting toilets and grey water systems (mainly microbiological hazards).

E. Establish user/operator type programs at local junior colleges to provide instruction on proper operation of these systems.

**County 5:**

A. Discussion on disposal of wastes.

B. Discussion on handling of wastes.

**County 6:**

No recommendations.

**County 7:**

A. Adequacy of units to compost waste and information on destruction of pathogens.

B. Recommend a means of disposal.

C. Environmental effects of these systems.

D. Frequency of maintenance.

E. Enforcement of procedures.

F. Frequency for enforcement.

**County 7:**

A. Adequacy of units to compost waste and information on destruction of pathogens.

B. Recommend a means of disposal.

C. Environmental effects of these systems.

D. Frequency of maintenance.

E. Enforcement of procedures.

F. Frequency for enforcement.

8. *WHAT TYPE OF MATERIAL SHOULD BE DEVELOPED FOR (A) YOU, AND (B) THE USER IN CONNECTION WITH THIS "EDUCATIONAL STUDY"? WHAT DO YOU WANT COVERED IN THIS MATERIAL?*

**County 1:**

A. Concern that a citizen may use state document to go over the head of local health officials for approval of their systems despite the hazards.

B. Overview on biological processes involved with these systems for distribution to users.

C. Overview on composting toilets and grey water systems.

D. What is purpose? Why are they needed?

E. Discussion for users and Health Department officials as to various means to organize and establish special district to organize and maintain these systems. Such things as discussion of Behr bill and legality of different types of special district for these types of uses.

F. Perhaps draft ordinance for these types of systems.

**County 2:**

Discussion on where these types of systems should be located, such as urban vs. rural use.

**County 3:**

A. Do not want to get involved in training of users.

B. Some type of statistical model showing where and what type of such systems can be used depending on type of area. In other words, a statistical model to determine the density for these types of systems.

C. Some discussion on where systems should and should not be installed (i.e., grey water system installed in areas where leachate can percolate properly through the soil.)

**County 4:**

A. Guidelines for construction and operation and maintenance for each type of system.

B. Educational information should include description of types of units available, principles on which they operate, ability of units to meet performance standards (such as a consumer evaluation type report) and various types of problems and concerns, social viewpoints, quality of final product, et cetera.

C. User information should include consumer report-type evaluations for various types of units and troubleshooting guidelines which are not too lengthy and can be readily used by user (should be a maximum of four pages).

**County 5:**

A. Need discussion of all types of alternative sewage disposal systems available with copies of designs so users can construct system based upon information given. Include grey water system standards.

B. Diagram of all systems which can be built by owner.

C. Recommend maintenance procedures.

D. Construction and maintenance guidelines.

E. Recommend disposal of wastes.

F. Example of alternative sewage disposal system ordinance.

**County 6:**

A. Need a realistic look at management of these systems from a nonrestrictive viewpoint.

B. Information provided to user on sensitivity of these types of units.

C. Information for local health department so they may provide necessary consultation. For example, what to look for during inspection and various types of troubleshooting recommendations.

**County 7:**

A. Pros and cons for use of the various types of systems including grey water systems.

B. Necessary diagrams.

C. Consumer success rate.

D. Operation and maintenance standards should not mention proprietary names.

E. Discussion of grey water disposal, why applicable in areas where a septic tank leach field could not operate. Key problem is the disposal of grey water.

## WATERLESS TOILETS SUMMARY

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Percent |
| TOTAL RESPONDING | 9 | 5 | 4 | 4 | 5 | 2 | 2 | 31 | |
| 5. Number of Usual Users (Average) | 2.55 | 3.00 | 2.25 | 1.5 | 3.8 | 4 | 3 | 2.9 | |
| **DESIGN** | | | | | | | | | |
| 7. Installation Cost: | | | | | | | | | |
| Less than $200 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 5 | 16 |
| $201–$500 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 6 |
| $501–$800 | 0 | 0 | 1 | 9 | 1 | 1 | 1 | 4 | 13 |
| More than $801 | 8 | 5 | 2 | 4 | 0 | 0 | 0 | 19 | 61 |
| No response | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| 8. Operating Cost per Year: | | | | | | | | | |
| Less than $25 | 9 | 5 | 3 | 1 | 5 | 2 | 2 | 27 | 87 |
| $26–$100 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 6 |
| More than $101 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 6 |
| 9. a. Long Chute? | | | | | | | | | |
| Yes | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 13 |
| No | 6 | 4 | 4 | 4 | 5 | 2 | 2 | 27 | 87 |
| b. Clogging of Chute? | | | | | | | | | |
| Yes | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| No | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 6 |
| No response | 7 | 4 | 4 | 4 | 5 | 2 | 2 | 28 | 90 |
| 10. Drain? | | | | | | | | | |
| Yes | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 6 |
| No | 9 | 4 | 4 | 4 | 4 | 2 | 1 | 28 | 90 |
| No response | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| 11. a. Leaks? | | | | | | | | | |
| Yes | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 6 | 19 |
| No | 9 | 5 | 4 | 2 | 3 | 2 | 0 | 25 | 81 |
| b. If Leaks, Where? | | | | | | | | | |
| Seams | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| Pinhole leak | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 5 | 16 |
| No response | 9 | 5 | 4 | 2 | 3 | 2 | 0 | 25 | 81 |
| c. If Leaks, Remedies? | | | | | | | | | |
| Coat barrels | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Add liner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 5 | 16 |
| No response | 9 | 5 | 4 | 2 | 3 | 2 | 1 | 26 | 84 |
| d. Groundwater Seepage? | | | | | | | | | |
| Yes | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 6 |
| No | 7 | 3 | 3 | 3 | 5 | 0 | 2 | 23 | 74 |
| No response | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 6 | 19 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Percent |
| 12. Urine Separation? | | | | | | | | | |
| Yes | 1 | 2 | 0 | 0 | 2 | 1 | 1 | 7 | 23 |
| No | 7 | 3 | 4 | 4 | 3 | 1 | 1 | 23 | 74 |
| No response | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 13. Lack of Volume? | | | | | | | | | |
| Yes | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 5 | 16 |
| No | 8 | 5 | 3 | 1 | 3 | 2 | 2 | 24 | 77 |
| No response | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 6 |
| 14. a. Heating Element? | | | | | | | | | |
| Yes | 2 | 1 | 4 | 4 | 0 | 0 | 0 | 11 | 35 |
| No | 7 | 4 | 0 | 0 | 5 | 2 | 2 | 20 | 65 |
| b. Operated Properly? | | | | | | | | | |
| Yes | 1 | 0 | 4 | 2 | 0 | 0 | 0 | 7 | 23 |
| No | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 10 |
| No response | 8 | 4 | 0 | 0 | 5 | 2 | 2 | 21 | 68 |
| 15. Mechanical Problems? | | | | | | | | | |
| Yes | 2 | 2 | 1 | 4 | 0 | 0 | 1 | 10 | 32 |
| No | 7 | 3 | 3 | 0 | 5 | 1 | 0 | 19 | 61 |
| No response | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 6 |
| 16. Unit Inside House? | | | | | | | | | |
| Yes | 8 | 5 | 4 | 4 | 0 | 0 | 0 | 21 | 68 |
| No | 1 | 0 | 0 | 0 | 5 | 2 | 2 | 10 | 32 |
| 17. a. Fan? | | | | | | | | | |
| Yes | 7 | 5 | 4 | 4 | 0 | 0 | 0 | 20 | 65 |
| No | 2 | 0 | 0 | 0 | 5 | 2 | 2 | 11 | 35 |
| b. Type | | | | | | | | | |
| Electric | 7 | 4 | 4 | 4 | 0 | 0 | 0 | 19 | 61 |
| Mechanical | 2 | 2 | 0 | 3 | 0 | 0 | 0 | 7 | 23 |
| No response | 2 | 0 | 0 | 0 | 5 | 2 | 2 | 11 | 35 |
| c. Used How Often? | | | | | | | | | |
| Each use | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 13 |
| Daily | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 13 |
| Weekly | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 3 | 3 | 2 | 3 | 0 | 0 | 0 | 11 | 35 |
| No response | 2 | 1 | 0 | 0 | 5 | 2 | 2 | 12 | 39 |
| 18. Vault Insulated? | | | | | | | | | |
| Yes | 6 | 5 | 1 | 0 | 0 | 0 | 0 | 12 | 39 |
| No | 3 | 0 | 3 | 2 | 5 | 2 | 2 | 17 | 55 |
| No response | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 6 |
| 19. a. Toilet Seat Seal? | | | | | | | | | |
| Yes | 6 | 4 | 1 | 3 | 4 | 1 | 2 | 21 | 68 |
| No | 3 | 1 | 3 | 1 | 1 | 1 | 0 | 10 | 32 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS Number | TOTALS Percent |
|---|---|---|---|---|---|---|---|---|---|
| b. Seat Kept Closed? | | | | | | | | | |
| Yes | 9 | 5 | 4 | 4 | 5 | 2 | 2 | 31 | 100 |
| No | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **MANAGEMENT** | | | | | | | | | |
| 20. Effort? | | | | | | | | | |
| None | 2 | 1 | 1 | 0 | 0 | 2 | 0 | 6 | 19 |
| Daily | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 4 | 13 |
| Weekly | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 5 | 16 |
| Monthly | 4 | 0 | 3 | 1 | 5 | 0 | 1 | 14 | 45 |
| Other | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 6 |
| 21. Effort Adequate? | | | | | | | | | |
| Yes | 9 | 3 | 4 | 4 | 5 | 1 | 0 | 26 | 84 |
| No | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 3 | 10 |
| No response | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 6 |
| 22. Importance of Efforts? | | | | | | | | | |
| Very | 3 | 2 | 1 | 3 | 2 | 0 | 0 | 11 | 35 |
| Moderately | 4 | 1 | 2 | 0 | 3 | 0 | 1 | 11 | 35 |
| Slightly | 2 | 1 | 0 | 1 | 0 | 0 | 1 | 5 | 16 |
| No importance | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 6 |
| No response | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 6 |
| 23. a. Pile Turned or Mixed? | | | | | | | | | |
| Daily | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 |
| Weekly | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 3 |
| Monthly | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 5 | 16 |
| Never | 7 | 5 | 3 | 0 | 0 | 2 | 2 | 19 | 61 |
| Other | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 5 | 16 |
| b. How Mixed? | | | | | | | | | |
| Mechanically | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 5 | 16 |
| By hand | 2 | 0 | 1 | 1 | 5 | 0 | 0 | 9 | 29 |
| No response | 7 | 5 | 2 | 0 | 0 | 2 | 2 | 18 | 58 |
| c. Success of Mixing? | | | | | | | | | |
| Very | 1 | 0 | 0 | 4 | 3 | 0 | 0 | 8 | 26 |
| Moderately | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 6 |
| Slightly | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| No response | 8 | 5 | 3 | 0 | 0 | 2 | 2 | 20 | 65 |
| 24. a. Contents Removed? | | | | | | | | | |
| Monthly | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 5 | 16 |
| 3 months | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| 6 months | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 13 |
| Yearly | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 5 | 16 |
| 2 years | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 4 | 13 |
| Other | 5 | 3 | 0 | 1 | 1 | 2 | 0 | 12 | 39 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS Number | TOTALS Percent |
|---|---|---|---|---|---|---|---|---|---|
| b. Disposed of in: | | | | | | | | | |
| Garden | 2 | 2 | 1 | 0 | 4 | 0 | 0 | 9 | 29 |
| Compost pile | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 5 | 16 |
| On-site burial | 3 | 2 | 1 | 0 | 0 | 1 | 2 | 9 | 29 |
| Off-site burial | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 5 | 16 |
| No response | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 6 | 19 |
| c. Condition: | | | | | | | | | |
| Earthy odor | 2 | 3 | 2 | 2 | 3 | 0 | 2 | 14 | 45 |
| Unpleasant odor | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 10 |
| Dry | 1 | 0 | 1 | 2 | 2 | 0 | 0 | 6 | 19 |
| Moist | 1 | 2 | 2 | 0 | 1 | 0 | 1 | 7 | 23 |
| Other | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 5 | 16 |
| No response | 6 | 1 | 1 | 0 | 0 | 2 | 0 | 10 | 32 |
| 25. a. Handling Equipment? | | | | | | | | | |
| Small shovel | 1 | 2 | 1 | 4 | 0 | 0 | 0 | 8 | 26 |
| Large shovel | 3 | 1 | 0 | 0 | 4 | 0 | 2 | 10 | 32 |
| Pitchfork | 1 | 1 | 0 | 0 | 3 | 0 | 0 | 5 | 16 |
| Rake | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 6 |
| Gloves | 1 | 1 | 0 | 2 | 0 | 0 | 2 | 6 | 19 |
| Other | 3 | 1 | 2 | 3 | 1 | 0 | 0 | 10 | 32 |
| No response | 4 | 2 | 1 | 0 | 0 | 2 | 0 | 9 | 29 |
| b. Specially marked? | | | | | | | | | |
| Yes | 2 | 2 | 1 | 3 | 1 | 0 | 0 | 9 | 29 |
| No | 3 | 1 | 2 | 1 | 3 | 0 | 2 | 12 | 39 |
| No response | 4 | 2 | 1 | 0 | 1 | 2 | 0 | 10 | 32 |
| 26. a. Liquid Buildup? | | | | | | | | | |
| Yes | 5 | 3 | 2 | 3 | 2 | 0 | 1 | 16 | 52 |
| No | 4 | 2 | 1 | 1 | 3 | 2 | 1 | 14 | 45 |
| No response | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| b. Solution? | | | | | | | | | |
| Drain | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 6 |
| Dry material | 3 | 1 | 1 | 3 | 1 | 0 | 0 | 6 | 19 |
| Ventilation | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 4 | 12 |
| Heat | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 10 |
| Other | 4 | 1 | 2 | 2 | 0 | 0 | 1 | 10 | 32 |
| No response | 4 | 2 | 2 | 1 | 3 | 2 | 1 | 15 | 48 |
| c. Solution Effective? | | | | | | | | | |
| Yes | 4 | 2 | 1 | 3 | 2 | 0 | 0 | 12 | 39 |
| No | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| No response | 4 | 3 | 3 | 1 | 3 | 2 | 2 | 18 | 58 |
| 27. a. Odors? | | | | | | | | | |
| Yes | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 15 | 48 |
| No | 6 | 3 | 1 | 1 | 3 | 1 | 1 | 16 | 52 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Percent |
| b. Frequency? | | | | | | | | | |
| Daily | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 10 |
| Weekly | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Monthly | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 10 |
| Other | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 9 | 29 |
| No response | 6 | 3 | 1 | 1 | 3 | 1 | 1 | 16 | 52 |
| c. Odor Solution? | | | | | | | | | |
| Dry material | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 5 | 16 |
| Mix more | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 6 |
| Ventilation | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 4 | 13 |
| Other | 2 | 2 | 1 | 2 | 1 | 0 | 0 | 8 | 26 |
| No response | 5 | 2 | 3 | 1 | 3 | 1 | 1 | 16 | 52 |
| 28. Install again? | | | | | | | | | |
| Yes | 8 | 4 | 3 | 1 | 3 | 2 | 2 | 23 | 74 |
| No | 1 | 1 | 1 | 3 | 1 | 0 | 0 | 7 | 23 |
| No response | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 3 |
| 29. Recommend to Others? | | | | | | | | | |
| Yes | 8 | 4 | 3 | 3 | 4 | 2 | 2 | 26 | 84 |
| No | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 10 |
| No response | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 6 |
| 30. a. Problems Interfered with Use? | | | | | | | | | |
| Yes | 0 | 2 | 1 | 3 | 1 | 0 | 0 | 7 | 23 |
| No | 9 | 3 | 2 | 1 | 4 | 2 | 2 | 23 | 74 |
| No response | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| b. With Psychological Acceptance? | | | | | | | | | |
| Yes | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 10 |
| No | 9 | 3 | 4 | 2 | 4 | 2 | 1 | 25 | 81 |
| No response | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 3 | 10 |
| **PILE COMPOSITION** | | | | | | | | | |
| 31. Start-up Material: | | | | | | | | | |
| Nothing | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 4 | 13 |
| Sawdust | 1 | 1 | 0 | 0 | 2 | 0 | 2 | 6 | 19 |
| Grass clippings | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 13 |
| Straw | 2 | 1 | 0 | 0 | 2 | 0 | 0 | 5 | 16 |
| Soil | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 10 | 32 |
| Peat moss | 7 | 4 | 3 | 4 | 0 | 0 | 0 | 18 | 58 |
| Other | 5 | 3 | 0 | 3 | 0 | 0 | 1 | 12 | 39 |
| 32. a. Wastes Added? | | | | | | | | | |
| Fecal matter | 9 | 5 | 4 | 4 | 5 | 2 | 2 | 31 | 100 |
| Urine | 8 | 4 | 4 | 4 | 5 | 1 | 1 | 27 | 87 |
| Kitchen refuse | 9 | 4 | 1 | 0 | 0 | 0 | 0 | 14 | 45 |
| Other | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 13 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS Number | TOTALS Percent |
|---|---|---|---|---|---|---|---|---|---|
| b. Frequency of Kitchen or Other Wastes? | | | | | | | | | |
| Daily | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 26 |
| Weekly | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 4 | 13 |
| Monthly | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 6 |
| No response | 0 | 1 | 3 | 4 | 5 | 2 | 2 | 17 | 55 |
| 33. a. Other Material Added? | | | | | | | | | |
| Yes | 9 | 2 | 3 | 4 | 5 | 1 | 2 | 26 | 84 |
| No | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 5 | 16 |
| b. Reason? | | | | | | | | | |
| Prevent liquid buildup | 2 | 0 | 2 | 2 | 1 | 0 | 1 | 8 | 26 |
| Aid composting | 7 | 2 | 2 | 1 | 1 | 0 | 2 | 15 | 48 |
| Other | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 4 | 13 |
| No response | 1 | 3 | 1 | 1 | 4 | 1 | 0 | 11 | 35 |
| c. Type of Material? | | | | | | | | | |
| Sawdust | 5 | 1 | 2 | 1 | 5 | 0 | 2 | 16 | 52 |
| Grass clippings | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| Peat moss | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 6 | 19 |
| Straw | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| Other | 3 | 2 | 2 | 2 | 1 | 1 | 0 | 11 | 35 |
| No response | 0 | 3 | 1 | 0 | 0 | 1 | 1 | 6 | 19 |
| d. Fresh or Green When Added? | | | | | | | | | |
| Yes | 4 | 1 | 1 | 0 | 1 | 0 | 0 | 7 | 23 |
| No | 4 | 1 | 2 | 4 | 4 | 0 | 2 | 17 | 55 |
| No response | 1 | 3 | 1 | 0 | 0 | 2 | 0 | 7 | 23 |
| e. Increase of Insects After? | | | | | | | | | |
| Yes | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| No | 6 | 2 | 3 | 3 | 5 | 0 | 1 | 20 | 65 |
| No response | 0 | 3 | 1 | 1 | 0 | 2 | 1 | 8 | 26 |
| f. Other Problems? | | | | | | | | | |
| Yes | 1 | 1 | 0 | 3 | 1 | 0 | 1 | 7 | 23 |
| No | 8 | 1 | 3 | 0 | 4 | 0 | 1 | 17 | 55 |
| No response | 0 | 3 | 1 | 1 | 0 | 2 | 0 | 7 | 23 |
| g. Frequency of Addition: | | | | | | | | | |
| After each use | 2 | 1 | 1 | 0 | 5 | 0 | 2 | 11 | 35 |
| Daily | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 6 |
| Weekly | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 5 | 16 |
| Monthly | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 16 |
| Other | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| No response | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 6 | 19 |

**WATERLESS TOILETS SUMMARY** (Continued)

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Percent |
| h. How Much Material? | | | | | | | | | |
| One cup | 1 | 1 | 0 | 2 | 1 | 0 | 1 | 6 | 19 |
| Two cups | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 6 | 19 |
| Three cups | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| One handful | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 10 |
| Two handfuls | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 6 |
| Other | 3 | 0 | 2 | 0 | 2 | 0 | 0 | 7 | 23 |
| No response | 2 | 3 | 1 | 1 | 0 | 1 | 0 | 8 | 26 |
| 34. Condition of Pile: | | | | | | | | | |
| Satisfactory | 5 | 4 | 3 | 3 | 4 | 1 | 1 | 21 | 68 |
| Too moist | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 7 | 23 |
| Too dry | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 13 |
| No response | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 6 |
| **VECTOR** | | | | | | | | | |
| 35. Insect Problem: | | | | | | | | | |
| No problem | 1 | 0 | 0 | 3 | 2 | 2 | 0 | 8 | 26 |
| Not too bad | 8 | 4 | 4 | 1 | 3 | 0 | 2 | 22 | 71 |
| Bad | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Terrible | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 36. Which Insects? | | | | | | | | | |
| House flies | 2 | 0 | 1 | 1 | 3 | 0 | 2 | 9 | 29 |
| Fruit flies | 5 | 5 | 3 | 0 | 0 | 0 | 0 | 13 | 42 |
| Spiders | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| Mites | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 6 |
| Other | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 |
| No response | 2 | 0 | 0 | 3 | 2 | 2 | 0 | 9 | 29 |
| 37. a. Tried to Control? | | | | | | | | | |
| Yes | 5 | 5 | 3 | 0 | 3 | 1 | 2 | 19 | 61 |
| No | 4 | 0 | 1 | 3 | 2 | 0 | 0 | 10 | 32 |
| No response | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 6 |
| b. How Controlled? | | | | | | | | | |
| Pest strip | 3 | 4 | 1 | 0 | 1 | 0 | 1 | 10 | 32 |
| Spraying | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 6 | 19 |
| Sticky tapes | 1 | 2 | 2 | 0 | 1 | 0 | 2 | 8 | 26 |
| Other | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 8 | 26 |
| No response | 4 | 0 | 1 | 4 | 2 | 1 | 0 | 12 | 39 |
| c. How Effective? | | | | | | | | | |
| Very | 4 | 3 | 0 | 0 | 2 | 0 | 0 | 9 | 29 |
| Moderately | 1 | 2 | 2 | 0 | 1 | 1 | 1 | 8 | 26 |
| Slightly | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| Ineffective | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| No response | 4 | 0 | 1 | 4 | 2 | 1 | 0 | 12 | 39 |
| 38. Rodents or Other Animals? | | | | | | | | | |
| Yes | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 6 |
| No | 8 | 4 | 4 | 4 | 4 | 2 | 2 | 28 | 90 |
| No response | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |

**WATERLESS TOILETS SUMMARY (Continued)**

| QUESTION | CLIVUS MULTRUM | TOA THRONE | MULLBANK | BIOLOO | FARALLONES VAULT | PIT PRIVY | 55-GALLON DRUM | TOTALS Number | TOTALS Percent |
|---|---|---|---|---|---|---|---|---|---|
| 39. a. Bathroom or Outhouse Screens? | | | | | | | | | |
| Yes | 3 | 5 | 2 | 0 | 2 | 2 | 0 | 14 | 45 |
| No | 6 | 0 | 1 | 4 | 2 | 0 | 1 | 14 | 45 |
| No response | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 10 |
| b. Vault Screens? | | | | | | | | | |
| Yes | 7 | 3 | 1 | 0 | 5 | 1 | 0 | 17 | 55 |
| No | 1 | 0 | 1 | 4 | 0 | 0 | 0 | 6 | 19 |
| No response | 1 | 2 | 2 | 0 | 0 | 1 | 2 | 8 | 26 |
| c. Vent Pipe Screens? | | | | | | | | | |
| Yes | 9 | 4 | 3 | 0 | 5 | 1 | 2 | 24 | 77 |
| No | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 5 | 16 |
| No response | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 6 |
| **ADDITIONAL CONSIDERATIONS** | | | | | | | | | |
| 40. Concern from Guests? | | | | | | | | | |
| Yes | 4 | 2 | 3 | 3 | 3 | 1 | 0 | 16 | 52 |
| No | 5 | 3 | 0 | 1 | 2 | 1 | 2 | 14 | 45 |
| No response | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 |
| 41. Other Problems? | | | | | | | | | |
| Yes | 3 | 2 | 1 | 0 | 1 | 0 | 1 | 8 | 26 |
| No | 4 | 3 | 2 | 3 | 4 | 2 | 0 | 18 | 58 |
| No response | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 5 | 16 |
| 42. Diet? | | | | | | | | | |
| Vegetarian | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 10 |
| Some meat | 7 | 5 | 3 | 2 | 3 | 2 | 2 | 24 | 77 |
| Lots of meat | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 3 | 10 |
| No response | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 43. Large Amounts of Liquid? | | | | | | | | | |
| Yes | 6 | 3 | 2 | 2 | 1 | 1 | 1 | 16 | 52 |
| No | 2 | 2 | 2 | 2 | 4 | 1 | 1 | 14 | 45 |
| No response | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 44. Fire? | | | | | | | | | |
| Yes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| No | 8 | 5 | 4 | 4 | 5 | 2 | 2 | 30 | 97 |
| No response | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 45. Rate Problems (Average Response): | | | | | | | | | |
| Odors | 2.4 | 2.25 | 2.26 | 2.25 | 2.6 | 2.5 | 2.0 | 2.32 | |
| Insects | 2.1 | 2.0 | 2.25 | 2.5 | 2.2 | 2.5 | 2.0 | 2.22 | |
| Liquid buildup | 2.6 | 2.2 | 2.5 | 2.25 | 2.6 | 3.0 | 2.0 | 2.45 | |
| Disposal | 2.8 | 2.8 | 2.7 | 2.0 | 2.8 | 3.0 | 2.5 | 2.66 | |
| Maintenance | 3.0 | 2.6 | 2.75 | 2.25 | 2.6 | 3.0 | 2.5 | 2.67 | |

## GREY WATER SYSTEMS SUMMARY

| QUESTION | SETTLING BOX AND LEACH FIELD | SLOW SAND FILTER | ANAEROBIC FILTER | NO TREATMENT | TOTALS | |
|---|---|---|---|---|---|---|
| | | | | | Number | Percent |
| TOTAL RESPONDING | 3 | 2 | 1 | 1 | 7 | |
| 3. Number of Users (Average) | 4 | 7 | 2 | 2 | 3.75 | |
| 4. Facilities Connected: | | | | | | |
| Bathtub | 1 | 1 | 1 | 1 | 4 | 57 |
| Shower | 2 | 2 | 0 | 1 | 5 | 71 |
| Bathroom sink | 1 | 1 | 1 | 1 | 4 | 57 |
| Kitchen sink | 2 | 2 | 1 | 0 | 5 | 71 |
| Washing machine | 3 | 0 | 1 | 1 | 5 | 71 |
| Other | 1 | 2 | 0 | 0 | 3 | 43 |
| 5. Installation Cost: | | | | | | |
| Less than $100 | 0 | 0 | 0 | 1 | 1 | 14 |
| $100–$500 | 2 | 2 | 1 | 0 | 5 | 71 |
| More than $500 | 1 | 0 | 0 | 0 | 1 | 14 |
| 6. Problems Due to System: | | | | | | |
| Odors | 1 | 1 | 0 | 0 | 2 | 29 |
| Insects | 0 | 0 | 0 | 0 | 0 | 0 |
| Clogging | 0 | 0 | 0 | 0 | 0 | 0 |
| 7. a. Filter on System: | | | | | | |
| Yes | 0 | 2 | 1 | 0 | 3 | 43 |
| No | 3 | 0 | 0 | 1 | 4 | 57 |
| b. Maintenance of Filter: | | | | | | |
| Wash rocks | 0 | 1 | 0 | 0 | 1 | 14 |
| Remove top sand layer | 0 | 1 | 0 | 0 | 1 | 14 |
| Flush with water | 0 | 0 | 1 | 0 | 1 | 14 |
| 8. Grease Buildup: | | | | | | |
| Yes | 0 | 0 | 0 | 0 | 0 | 0 |
| No | 3 | 2 | 1 | 1 | 7 | 100 |

GREY WATER SYSTEMS SUMMARY (Continued)

| QUESTION | SETTLING BOX AND LEACH FIELD | SLOW SAND FILTER | ANAEROBIC FILTER | NO TREATMENT | TOTALS | |
|---|---|---|---|---|---|---|
| | | | | | Number | Percent |
| 9. a. Disposal Area: | | | | | | |
| Vegetable garden | 1 | 0 | 0 | 0 | 1 | 14 |
| Leach field | 2 | 1 | 1 | 0 | 4 | 57 |
| Flower garden | 0 | 1 | 0 | 1 | 2 | 29 |
| Trees | 0 | 0 | 1 | 1 | 2 | 29 |
| b. Problems in Disposal Area: | | | | | | |
| Yes | 2 | 0 | 0 | 0 | 2 | 29 |
| No | 1 | 2 | 1 | 1 | 5 | 71 |
| c. Types of Problems: | | | | | | |
| High groundwater | 1 | 0 | 0 | 0 | 1 | 14 |
| Surfacing of effluent | 1 | 0 | 0 | 0 | 1 | 14 |
| 10. Other problems: | | | | | | |
| Yes | 0 | 0 | 0 | 0 | 0 | 0 |
| No | 3 | 2 | 1 | 1 | 7 | 100 |
| 11. Recommend to Others: | | | | | | |
| Yes | 3 | 2 | 1 | 1 | 7 | 100 |
| No | 0 | 0 | 0 | 0 | 0 | 0 |